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PHASE III:
CRS PREDICTION MODEL DEVELOPMENT

By

Laura B. Heckel, P.E.
Heckel Engineering, Research, and Education, Inc.

Yanfeng Ouyang, Ph.D.
University of Illinois at Urbana-Champaign

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16. Abstract

The Illinois Department of Transportation (IDOT) determines a Condition Rating Survey (CRS) value for each roadway section using CRS calculation models. After the rating values have been determined, IDOT uses prediction models to estimate the condition of the pavements in the future. The objective of Phase 3 was to revise the existing prediction models and develop new models for pavement types that currently have none.

Models were created or revised for 28 pavement types. Both D-cracking and the use of SMART (thin overlays) are known to reduce the expected life of pavements. Therefore, D-cracking and SMART models were created whenever possible.

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Members of the Technical Review Panel are the following:

David Felts, IDOT – OPP, chair
Travis Lobmaster, IDOT – OPP
Keith Sherman, IDOT – OPP
LaDonna Rowden, IDOT – BMPR
Philip Limes, IDOT – District 5
Kevin Pollock, IDOT – District 8

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EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) determines a Condition Rating Survey (CRS) value for each roadway section using CRS calculation models. After the rating values have been determined, IDOT uses prediction models to estimate the condition of the pavements in the future. The objective of Phase 3 was to revise the existing prediction models and develop new models for pavement types that currently have none.

The accuracy of grouping Districts 1 through 4 and Districts 5 through 9 for analysis was examined. Existing models use this division, accounting for environmental effects on performance. This division was accurate for asphalt-surfaced pavements and was retained for model revision. Concrete pavements perform similarly regardless of location in the state, so no division was used for most concrete models.

Existing prediction models use a two-slope method, with a break point at a CRS value of 6.5. The two slopes are used for current CRS values greater than or equal to 6.5 and less than 6.5. Subtracting the slope value times the number of years in the future desired from the current CRS predicts the future condition of pavements. This research determined that a break point of 5.5 is more accurate for asphalt-surfaced pavements. Conversely, a break point of 7.0 was more accurate for concrete pavements.

Models were created or revised for 28 pavement types. Both D-cracking and the use of SMART (thin overlays) are known to reduce the expected life of pavements. Therefore, D-cracking and SMART models were created whenever possible.

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1. INTRODUCTION

Since 1995, the Illinois Department of Transportation (IDOT) has been using calculation models to determine Condition Rating Survey (CRS) values and performance models to predict the future condition of state-maintained pavements. Both CRS calculation and prediction models were developed from the Illinois Roadway Information System (IRIS) database. Phase 1 of this project identified the calculation and prediction models most in need of revision and identified pavement types for which no models currently exist. Phase 2 involved the revision and creation of CRS calculation models. The subject of this report, Phase 3, entails the creation and revision of CRS prediction models.

Research conducted in 1994 by ERES Consultants, Inc. created performance prediction models based on IDOT's CRS values and the age of the pavements that were stored in IRIS (ERES Consultants, 1994). The modeling process developed by ERES included identifying individual pavement sections and their CRS values over time. A rate of change (slope) of CRS over time can be determined for each pavement section by calculating the change in CRS divided by the change in age. Once each slope is calculated, an average slope of all the slopes is determined. This average slope is the prediction model for pavements of similar design. Using this one-slope method, the equation for the calculation of future CRS values is as follows:

Future CRS = Current CRS – slope*years of prediction

In 1999, Darter, et al., conducted research using the Illinois Pavement Feedback System (IPFS) database, which contains information on interstate pavements only (Darter, et al., 1999). The result of the research recommended adopting a two-slope method instead of the one-slope method used since 1995. Plots of the traces of many asphalt-surfaced roadways revealed a quick decrease in CRS, then a slower decrease over time. Many concrete pavements showed an opposite trend, staying at a high CRS range for a long period of time, and then declining more rapidly. A CRS value of 6.5 was determined to be the best value for the break in slope. New models were recommended using the two-slope method and data from IRIS, which contains CRS information on all state-maintained pavements. The 6.5 break point as the best break point was not evaluated with IRIS data. The new prediction models have the form:

If current CRS $\geq$6.5, Future CRS = Current CRS – $\text{slope}_{9.0\text{-}6.5}$*years of prediction

If current CRS <6.5, Future CRS = Current CRS – $\text{slope}_{6.5\text{-}1.0}$*years of prediction

Both the 1995 and 1999 research recognized a difference in performance between roadways in the northern half of the state and the southern half of the state. Prediction models were developed for pavements in Districts 1 through 4 and pavements in Districts 5 through 9. In the early 2000s, the prediction models for all pavements, both interstate and non-interstate, were revised using the two-slope method, without examining the break point or the district division.

The research objectives of Phase 3 were to create or revise the prediction models for all pavement types, using data from IRIS. IPFS data was not used, because it does not contain information on the non-interstate system. The grouping of Districts 1 through 4 and Districts 5 through 9 and the use of a CRS value of 6.5 as the break point in the two-slope models were also examined. The results of these efforts are contained in this report.

2. DATA PREPARATION

Data was retrieved from IRIS, cleaned and grouped, and prepared for model development. This section details these steps.

2.1 OBTAINING, CLEANING, AND CONSOLIDATING DATA

Data from every odd year from 1993 through 2005 were retrieved from IRIS. Because of the rotating schedule of District CRS surveys, this resulted in seven surveys of every IDOT-maintained roadway, from 1992 through 2005. Data from the 2006 surveys were not used, because the districts surveyed that year would have had one more survey than the districts not surveyed that year.

In most data sets, there are inevitable “problems” that must be cleaned. Data were cleaned in two ways. First, records in each data file that did not match the two CRS years included in that database were deleted. Second, records with a surface type code and pavement distresses that did not match were also deleted. An example of this is a record with a 620 surface type code (asphalt overlay of jointed reinforced concrete pavement) and distress codes A through K (concrete surface distresses). After cleaning, the data from all seven databases were assembled into one database.

The combined database needed to be consolidated down to a more manageable size. IRIS contains fields for approximately 150 items, including items that pertain to the roadway’s physical characteristics, location, functional classification and many other types of items. A change in any of these items causes a break in the section, and an additional record in the database. Only fields pertaining to pavement type, construction date, and condition were needed for this project. The following items were used to perform this study:

- District
- County
- Marked Route
- Key Route
- Beginning Station
- Ending Station
- Original Construction Year
- Surface Construction Year
- Surface Type
- AADT Count
- Multi Unit Count
- Heavy Commercial Count
- CRS Year
- CRS
- Pavement Distresses

The database was consolidated on the above items, using the minimum beginning station, maximum ending station, and average values for AADT Count, Multi Unit Count, and Heavy Commercial Count. Each individual year’s database contained approximately 100,000 lines as received. After combining all years’ data and consolidating on the items enumerated above, the combined database contained approximately 120,000 lines.

2.2 AGE CALCULATION

After data cleaning and grouping were completed, the age of each pavement section at the time of CRS evaluation was calculated. A new field called Latest Surface Date was added to the database and updated as follows:

- Original Construction Year if Surface Construction Year was blank.
- Surface Construction Year if Surface Construction Year was later than Original Construction Year (most records), or if Original Construction Year was blank.
- Delete record if Original Construction Year was later than Surface Construction Year, both Original Construction Year and Surface Construction Year were blank, or if Latest Surface Date was later than CRS Year (negative age).

Once the Latest Surface Date was determined, age was calculated as follows:

Age = CRS Year – Latest Surface Date

The accuracy of the Latest Surface Date is in doubt for many pavement sections. When graphs of the pavement traces are plotted, it is evident that the original construction year and surface construction year are not always updated when rehabilitation or new construction occurs. This can be seen in Figure 1, where there are many traces that begin at a 9.0 CRS at 10, 20, or even 30 years of age. Because age is dependent on Original Construction Year, Surface Construction Year, and CRS Year, the Original Construction Year and/or Surface Construction Year must not have been updated when rehabilitation or construction caused the CRS to reset to 9.0.

Figure 1. Example of inaccurate age information.

The model development procedure of calculating slopes and average slopes compensates for the inaccurate age information. Because the model is a function of slopes, the location of the slopes with respect to age is inconsequential.

2.3 DATA SORTING

To be able to build the traces for each pavement section, the section has to be uniquely identified and the age and CRS values must be in order. The Latest Surface Date needs to be considered as a unique identifying feature of a pavement section. There were many pavement sections for which all identifying features were identical, except the Latest Surface Date. Sorting by increasing age but failing to keep the Latest Surface Date as an identifying feature of the pavement section caused traces to be inaccurate. An example of this is a pavement section that was rehabilitated during the analysis period. The age of the section would reset to zero at the time of the rehabilitation. The resulting trace is unusable. The pavement section's CRS values and age need to be treated as if it were a new pavement section.

The data were sorted in increasing order as follows, to uniquely identify pavement sections and to create traces:

- District
- County
- Marked Route
- Key Route
- Beginning Station
- Ending Station
- Latest Surface Date
- CRS Year

In 2005 and again in 2006, some counties were shifted to new districts. The effect of this on the consolidated database is that some roadway sections would be identified in two different districts in the course of the 1992 to 2005 analysis period. This would create a break in the trace, and some slopes would be lost. Therefore, the historical data for all realigned counties were updated to the district to which they currently belong.

2.4 FLAG D-CRACKING AND SMART PROJECTS

Historical research has shown that D-cracking has a negative impact on the deterioration rate of a pavement section (Hall, et. al., 1994). For this reason, the research performed in both 1994 and 1999 created separate prediction models for both bare concrete and overlays of concrete where D-cracking had been identified. Research conducted this year also identified D-cracking as negatively impacting performance. Identifying D-cracking pavements was done by flagging all bare concrete pavements that contained the A distress code (D-cracking) and all asphalt overlays of concrete that contained the X distress code (Reflective D-cracking) in the Pavement Distress field.

The Department uses a program called Surface Maintenance at the Right Time (SMART) for some asphalt overlays. These projects are thin overlays of pavements that are not excessively deteriorated (Bureau of Design and Environment Manual, 2002). Because the overlays are thin, the expected deterioration rate is higher than that for standard overlays. For this research, all SMART projects needed to be identified and considered separately.

There is no field in IRIS that identifies a roadway section as having a SMART overlay. Therefore, the annual programs for 1987 through 2005 were scanned to find all SMART projects. IDOT provided a spreadsheet that listed SMART projects for 1987 through 2002 and included key route stationing of the project. For 2003 through 2005, IDOT provided downloads of the annual programs that contained key route stationing. A list of all SMART projects was compiled from these documents. This list was then compared to the assembled database and a project was flagged as SMART if the CRS values were consistent with rehabilitation performed during the year the project was listed in the annual program. As noted earlier, due to inaccuracies in Surface Construction Year, this data element could not be used to accurately identify SMART projects. A field in IRIS that identifies a project as having a SMART overlay is highly recommended for future tracking of the performance of this type of overlay.

The D-cracking and SMART projects were analyzed independently. There were only 9 records that were flagged as both D-cracking and SMART; these projects were not included in the analysis for either D-cracking or SMART.

3. MODEL DEVELOPMENT PROCESS

This section details the model development process. The development process included the following items:

- Grouping of IRIS' surface type codes into similar pavement types
- Utilizing performance modeling software
- Developing a new graphing procedure
- Examining grouping of Districts 1 through 4 and Districts 5 through 9 for analysis
- Analyzing the applicability of a CRS of 6.5 as the break point
- Identifying the model selection criteria

3.1 PAVEMENT TYPES

As in the development of CRS calculation models, surface type codes were combined by similarity into pavement types (Heckel and Ouyang, 2007). The surface type codes and definitions identified by IDOT and used in IRIS are included in Appendix A. Table 1 lists the pavement types used in the analysis. Even where data were sparse, model development was attempted to ensure IDOT could predict performance into the future for as many pavement types as possible.

Table 1. Pavement Types

System	Pavement Type	Surface Codes
Interstate	Asphalt Concrete Pavement (ACP)	550 and 560
	Asphalt Overlays of Jointed Plain Concrete Pavement – Unknown or No Reinforcement (AC/JPCP)	600 through 615
	Asphalt Overlays of Jointed Reinforced Concrete Pavement – Partial or Full Reinforcement or Hinge Joints (AC/JRCP)	620 through 630
	Asphalt Overlays of Continuously Reinforced Concrete Pavement (AC/CRCP)	640
	Jointed Reinforced Concrete Pavement – Partial or Full Reinforcement (JRCP)	720, 730, 760 through 772, 780, 782
	Hinge Jointed Concrete Pavement (HJCP)	725, 775, and 777
	Continuously Reinforced Concrete Pavement (CRCP)	740, 790, and 792
	Combination – asphalt predominant	95x and 96x
	Combination – concrete predominant	97x

(continued on page 7)

Table 1. Pavement Types (continued)

System	Pavement Type	Surface Codes
Non-Interstate	Unimproved	010 through 210
	Asphalt Surface Treated – Low Type (ACSTLT)	300
	Asphalt Concrete Pavement – Low Type (ACPLT)	400 and 410
	Asphalt Surface Treated – High Type (ACSTHT)	500
	Asphalt Concrete over Rubblized Concrete (AC/Rubb)	501 through 540
	Asphalt Concrete Pavement – High Type (ACP)	550 and 560
	Asphalt Overlays of PCC – Unknown Reinforcement (AC/PCCun)	600
	Asphalt Overlays of Jointed Plain Concrete Pavement – No Reinforcement (AC/JPCP)	610 and 615
	Asphalt Overlays of Jointed Reinforced Concrete Pavement – Partial or Full Reinforcement or Hinged Joints (AC/JRCP)	620 through 630
	Asphalt Overlays of Continuously Reinforced Concrete Pavement (AC/CRCP)	640
	Asphalt Overlays of Brick, Block, or Other (AC/BBO)	650
	PCC – Unknown Reinforcement (PCCun)	700, 760, and 762
	Jointed Plain Concrete Pavement – No Reinforcement (JPCP)	710, 765, and 767
	Jointed Reinforced Concrete Pavement – Partial or Full Reinforcement (JRCP)	720, 730, 770, 772, 780, and 782
	Hinge Jointed Concrete Pavement (HJCP)	725, 775, and 777
	Continuously Reinforced Concrete Pavement (CRCP)	740, 790, and 792
	Brick, Block or Other (BBO)	800
	Combination – asphalt low type predominant	90x through 94x
	Combination – asphalt high type predominant	95x
	Combination – asphalt overlays of concrete predominant	96x
	Combination – concrete predominant	97x
	Combination – brick, block, or other predominant	98x

To the extent possible, these pavement groups were also used for D-cracking and SMART pavements. In some cases, pavement types needed to be combined further to have sufficient data for modeling.

3.2 PERFORMANCE MODELING SOFTWARE

The Performance Modeling Wizard that ERES created in 1995 was again used to create and revise the models (ERES Consultants, 1995). The data from the pavement types identified in the previous section are imported into the software and filtered to identify the specific subset of data for study. The attributes that uniquely identify a pavement section are designated. There are options for “cleaning” the traces. These are:

- Risers
- Flats
- Isolated points

Risers are two consecutive CRS values where the CRS increased with age. Flats are two consecutive CRS values that did not change with age. Isolated points cannot be used, because no slope can be determined. Cleaning them prevents them from being shown on the graph.

For this study, as in the past studies, all rising slopes were eliminated, as were isolated points. For the vast majority of road sections, the CRS only increases when rehabilitation or maintenance is performed, causing the roadway to be a “new” section. Flats were kept in the analysis initially, as it is possible for a pavement section to remain at the same CRS level for two years.

After the previous step is completed, the software calculates the average slope from all the slopes in the clean data set. The model and a graph of the slopes and model are presented. A graph can only be shown if the maximum number of years of data multiplied by the number of clean traces is less than 3,800. There were several data sets for which graphs were not available.

The data above and below the break point are analyzed separately to develop unique models for the two CRS ranges. The model development software cannot display both data sets and models on the same graph.

3.3 NEW GRAPHING PROCEDURE

The graphing size limitations and inability to see all data and models of a particular pavement type of the Performance Modeling Wizard impacted the ability to analyze the accuracy of the resulting models. For these reasons, a new graphing procedure was developed for use with a spreadsheet.

The new procedure shows up to 256 traces on a graph, allowing partial or complete graphing of every data set. The new procedure has the added advantage of being able to show all the CRS ranges and corresponding models for a given pavement type on one graph.

3.4 DISTRICT GROUPING

The accuracy for modeling of dividing the state into Districts 1 through 4 in the northern half of the state and Districts 5 through 9 in the southern half of the state was evaluated. For each pavement type listed in Section 3.1, models were determined for each district separately. The data and models for each district were then compared to the others to see if this district split held true. For the asphalt-surfaced pavement types, the grouping of Districts 1 through 4 and 5 through 9 was the best split, reflecting the environmental effects on performance. For most concrete pavement types, however, this trend was not seen. In fact, no division at all seemed necessary, as concrete pavements throughout the state performed in a similar manner, indicating less sensitivity to the environment.

As an example, Table 2 shows the models by district for the interstate overlays of continuously reinforced concrete pavements and bare continuously reinforced concrete pavements. For the AC/CRCP pavement type, all models for Districts 1 through 4 are greater than 0.300, whereas all models for Districts 5 through 9 are less than 0.300, with the exception of District 8. For the CRCP pavement type, the models are all similar, with the exception of District 2. Both observations were consistent throughout other pavement types.

Table 2. Prediction Models by District

District	AC/CRCP Model	CRCP Model
1	0.346	0.128
2	0.304	0.247
3	0.346	0.151
4	0.336	0.177
5	0.278	0.170
6	0.214	0.152
7	0.280	0.169
8	0.340	0.152
9	0.191	0.162

The division of districts into northern and southern areas illuminates an environmental effect on the performance of asphalt-surfaced pavements. Other factors also affect performance, such as quality of materials used in construction, maintenance practices, and traffic. Traffic effects were examined by ERES in 1995 and found not to correlate well with performance. Because IDOT's pavement designs include a traffic component, the effect of traffic is minimized in performance. Materials and maintenance are not included in the IRIS database, so they are not examined here.

3.5 CRS 6.5 BREAK POINT AND FLATS

Another objective of the research was to determine the accuracy of a CRS of 6.5 as the break point in the two-slope models. Initially, using the previous graphing method, the 6.5 break point seemed accurate. Only when the new graphing procedure was used did it become evident that a new break point may be more accurate. For most asphalt-surfaced pavements, a CRS of 5.5 was more accurate, as determined graphically.

While using the CRS 5.5 break point for asphalt-surfaced pavements improved the accuracy of the models, most models were still above the bulk of the data. Removing the flats, where the CRS stayed the same for consecutive surveys, improved the accuracy of the models further. Figure 2 shows an example of the different break points for an asphalt-surfaced pavement data set. Again, the Latest Surface Date is prone to inaccuracy, causing some pavement traces to appear to be outliers. Because the model form uses only slopes, the location of the traces with respect to age is inconsequential.

Figure 2. Difference between 5.5 and 6.5 break points on asphalt-surfaced pavements.

Using the 6.5 break point, the deterioration for most pavements with a starting CRS between 6.5 and 5.5 would have been under-predicted, as the 6.5 to 1.0 model is above most of the data in that CRS range. Using 5.5 as the break point and removing the flats, the models go through the center of the bulk of the data. The age to the 5.5 break point increases, because the pavements have had a longer period of time to reach a CRS of 5.5.

Concrete pavements have the opposite trend. A break point of 7.0 seems to be more accurate for these pavements. Figure 3 shows the difference between 7.0 and 6.5 break points on a concrete pavement data set.

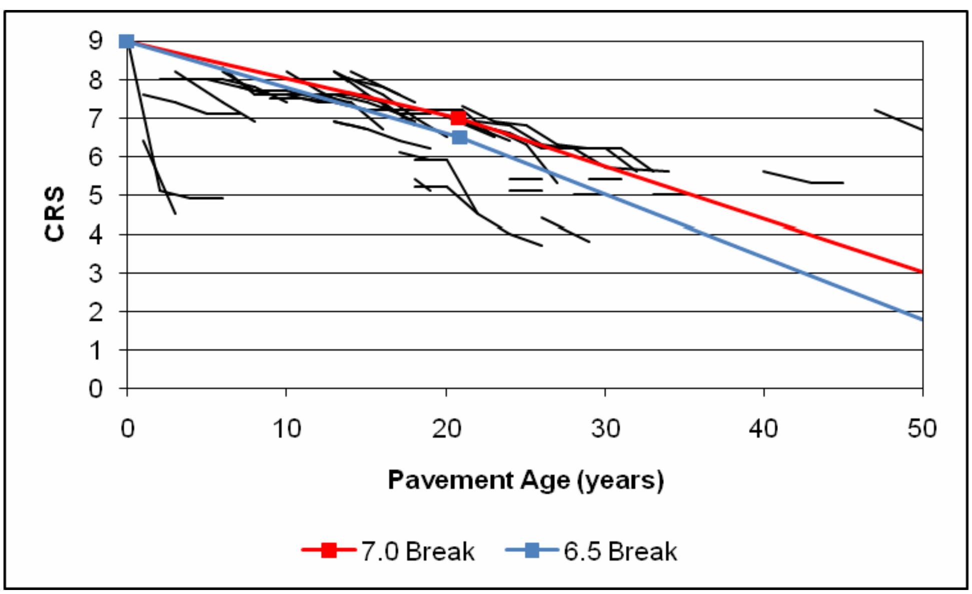

Figure 3. Difference between 7.0 and 6.5 break points on concrete pavements.

Using CRS 6.5 as the break point would cause the Department to over-predict the deterioration of pavements with a starting CRS of 7.0 and lower. Using CRS 7.0 as the break point, the models go through the center of the bulk of the data. Leaving the flats in for analysis was appropriate, as concrete pavements do seem to stay at the same CRS for multiple CRS periods. Removing the flats would have made the slope of the models steeper and less accurate. The age at the break point for this pavement type is similar, due to the similarity of the slopes from 9.0 to 6.5 and 9.0 to 7.0.

Having examined the accuracy of the CRS 6.5 break point, it is recommended to use a CRS of 5.5 as the break point for asphalt-surfaced pavements and a CRS of 7.0 as the break point for concrete pavements. The models using the revised break points are recommended for implementation in Section 4.

3.6 MODEL CREATION AND REVISION

Models were created for every pavement type by northern and southern areas of the state, to examine the necessity of splitting the data by area. When a difference between the northern and southern districts was apparent, two models were created, one for each area. When no difference was noted, the districts were all modeled together. Additionally, two-slope models were created whenever there were sufficient data above and below the break point. Models were also created for D-cracked pavements and SMART pavements. So, for a given pavement type, there may be six models, as follows:

- Standard Model: Districts 1 through 4, slopes above and below break point
- Standard Model: Districts 5 through 9, slopes above and below break point
- D-cracking Model: Districts 1 through 4, slopes above and below break point
- D-cracking Model: Districts 5 through 9, slopes above and below break point
- SMART Model: Districts 1 through 4, slopes above and below break point
- SMART Model: Districts 5 through 9, slopes above and below break point

Because both the presence of D-cracking and the use of thinner overlays are expected to decrease the life of a pavement, no model was recommended that would indicate a longer life than the standard model for D-cracking and SMART pavements. Instead, the standard model was recommended in those instances.

4. RECOMMENDED PREDICTION MODELS

The models recommended for implementation are presented in this section, using the district split and break points identified in the model development process. The standard model, D-cracking model (where appropriate), and SMART model (where appropriate), for each pavement type are described. Because D-cracking is a concrete phenomenon, there are only D-cracking models for bare concrete and overlays of concrete pavements. Similarly, since SMART projects are asphalt overlays by definition, there are no SMART models for bare concrete pavements.

For every pavement type, the current and proposed models are presented in a table. Graphs showing the data used in model development and the current and proposed models are also included. Markers are only shown on the model lines if a break point is used in the models. Pavement sections with inaccurate age information are included on the graphs, because the slopes for those pavement sections are valid and useful in model development. The models are extrapolated on the graphs below the CRS level for which there is data. These extrapolations are shown as dashed lines.

For each pavement type, the number of years for the models to deteriorate from a CRS of 9.0 to a CRS of 4.5 is included. IDOT considers pavements to be in poor condition at a CRS of 4.5 and below.

4.1 INTERSTATE ACP

Table 3 contains the current and proposed models for this pavement type. D-cracking is not applicable to this pavement type, and no SMART projects have been constructed.

Table 3. Interstate ACP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.180	0.180	0.451	0.451
	5 – 9	0.180	0.180	0.272	0.272

Note: Below CRS of 4.0, the models are estimated.

Where there is currently only one model for all districts and CRS ranges, separate models were developed for Districts 1 through 4 and 5 through 9. Both proposed standard models are steeper than the current model, and more closely represent the data, as seen in Figure 4 and Figure 5. As the interstate ACP sections age, more data will become available to fine-tune the models.

When more data are available, a CRS break point of 5.5 should be explored. Table 4 includes the number of years to CRS values of 4.5. The proposed models predict a shorter life for full-depth asphalt concrete pavements than the current models.

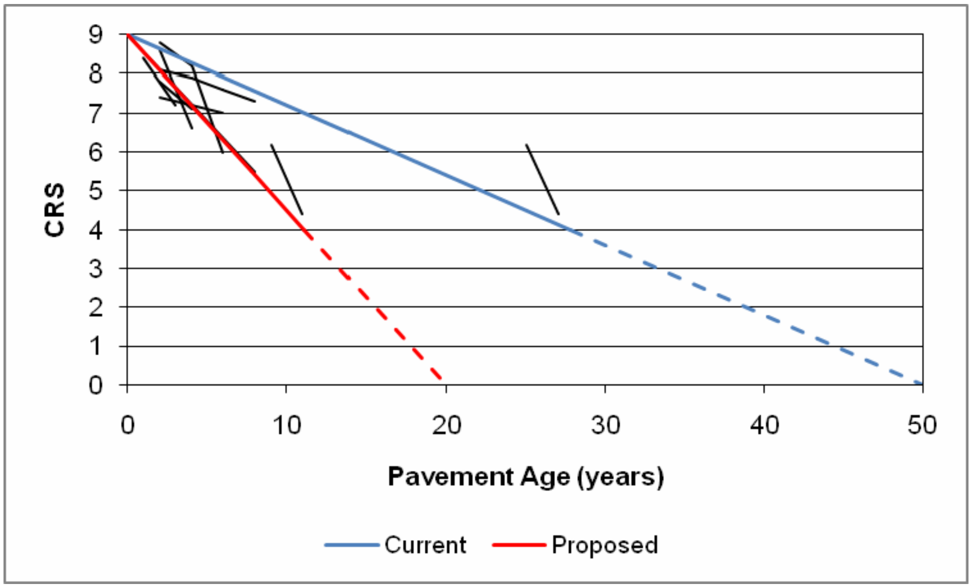

Figure 4. Interstate ACP, districts 1 through 4.

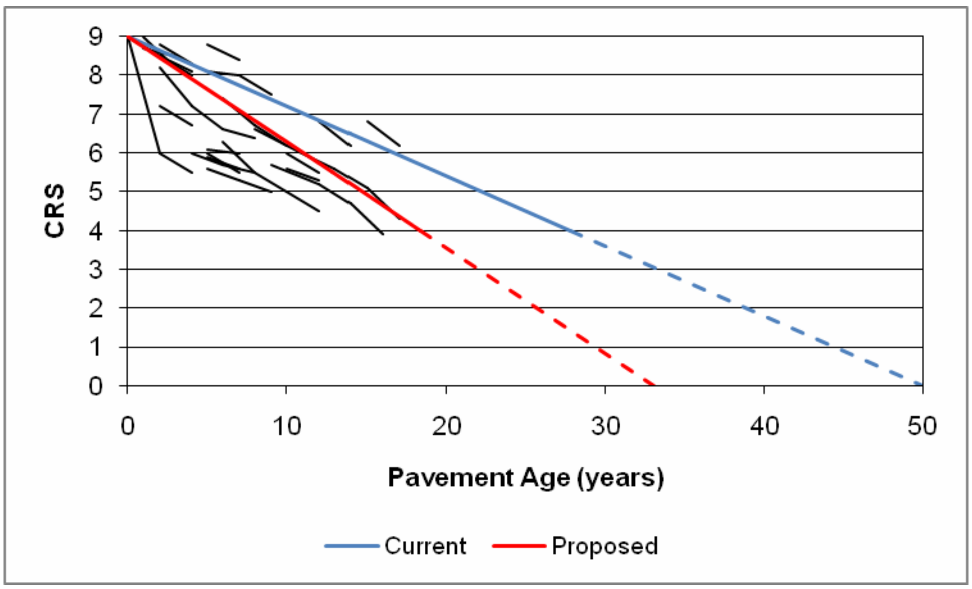

Figure 5. Interstate ACP, districts 5 through 9.

Table 4. Interstate ACP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	25.0	10.0
	5 – 9	25.0	16.5

4.2 INTERSTATE AC/JPCP

There currently are no models for this pavement type. Table 5 contains the proposed models.

Table 5. Interstate AC/JPCP Models

		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.299	0.264
D-Cracking	1 – 4	0.299	0.264
	5 – 9	0.491	0.491
SMART	1 – 9	0.425	0.200

Note: Below CRS of 4.0, the models are estimated.

Figure 6 shows the data and proposed standard model.

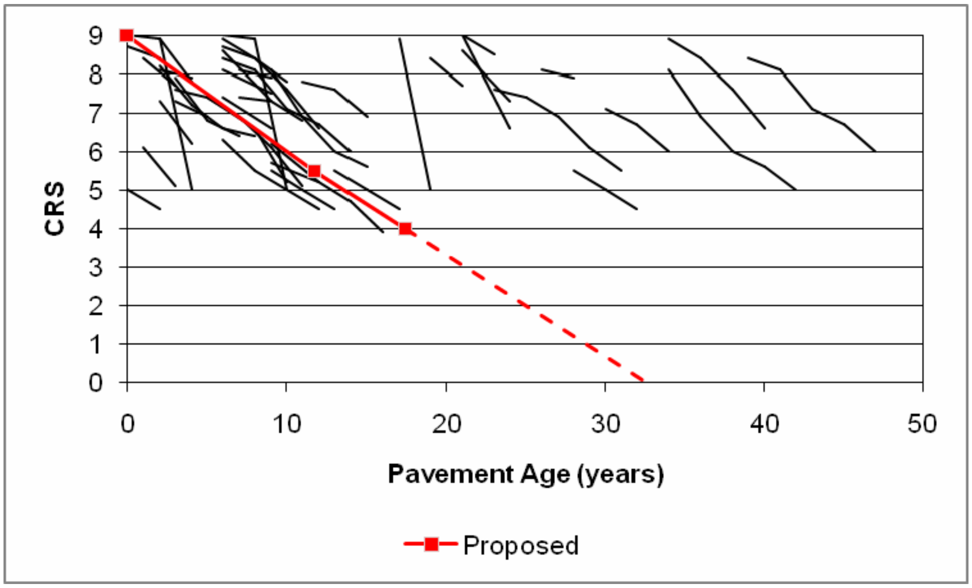

Figure 6. Interstate AC/JPCP.

Due to the limited amount of data, D-cracking records for AC/JPCP, AC/HJCP, and AC/JRCP on the interstate system were combined by area of the state for model development. Because the D-cracking model for the northern districts indicated better performance than the standard model, the standard model is used for D-cracking in those districts. The graph is shown here in Figure 7, and is not repeated in the AC/HJCP and AC/JRCP sections. The proposed model is steeper than the current models for all interstate asphalt overlays of concrete pavements.

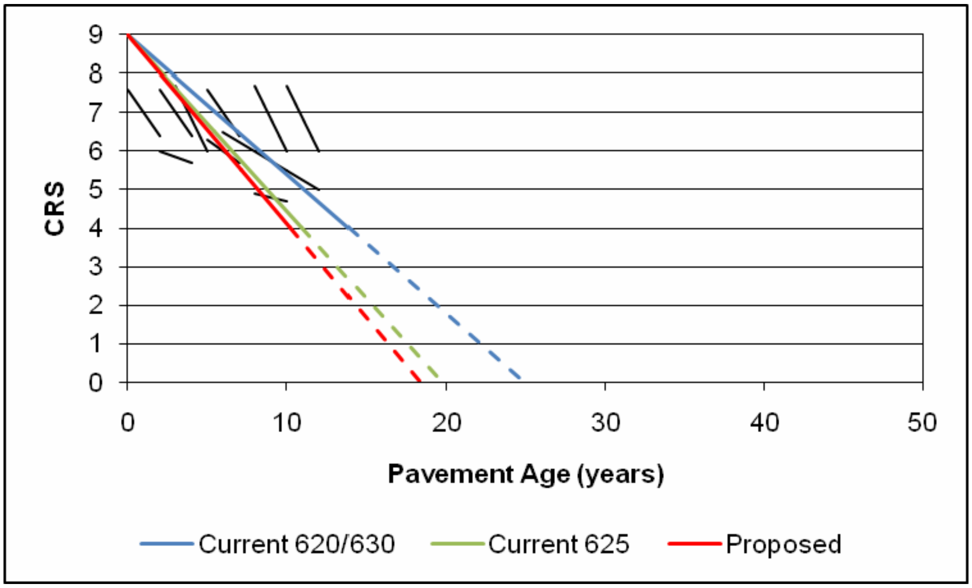

Figure 7. D-cracking interstate AC/JPCP and AC/JRCP, districts 5 through 9.

Figure 8 shows the models for interstate SMART AC/JPCPs. There is no model currently for this pavement type. While the rate of deterioration between CRS 5.5 and 1.0 is similar to the standard model, the rate between CRS 9.0 and 5.5 is much steeper than the standard model.

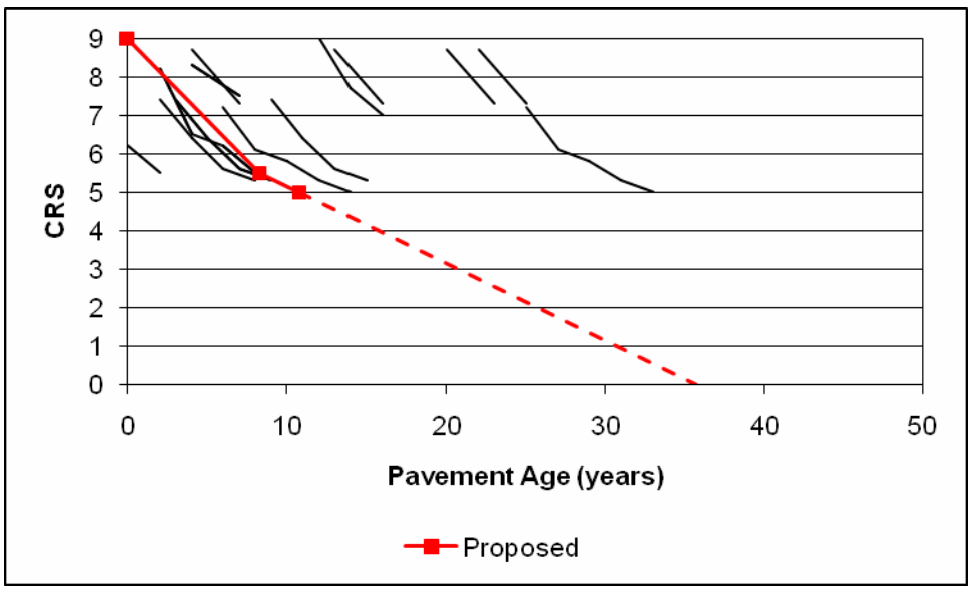

Figure 8. SMART interstate AC/JPCP.

Table 6 shows the number of years for the models to reach CRS values of 4.5. Because there are currently no models for this pavement type, no comparison is possible.

Table 6. Interstate AC/JPCP Years to CRS 4.5

Model Type	Districts	Proposed (years)
Standard	1 – 9	15.5
D-Cracking	1 – 4	15.5
	5 – 9	9.2
SMART	1 – 9	13.2

4.3 INTERSTATE AC/HJCP AND AC/JRCP

There was only one record of AC/HJCP on the interstate system in the database. Due to similarity of design, the models developed for AC/JRCP may be used for this pavement type as well. Because the current AC/HJCP models are different from the current AC/JRCP models, a separate table is shown for each pavement type. Table 7 contains the current and proposed models for AC/HJCP roadways, and Table 8 contains the models for the AC/JRCP pavement sections.

Table 7. Interstate AC/HJCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.339	0.169	0.358	0.239
	5 – 9	0.339	0.169	0.331	0.206
D-Cracking	1 – 4	0.339	0.169	0.333	0.253
	5 – 9	0.456	0.456	0.491	0.491
SMART	1 – 4	0.257	0.194	0.426	0.426
	5 – 9	0.222	0.150	0.426	0.426

Note: Below CRS of 4.0, the models are estimated.

Table 8. Interstate AC/JRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.379	0.379	0.358	0.239
	5 – 9	0.289	0.289	0.331	0.206
D-Cracking	1 – 4	0.474	0.474	0.333	0.253
	5 – 9	0.361	0.361	0.491	0.491
SMART	1 – 4	0.257	0.194	0.426	0.426
	5 – 9	0.222	0.150	0.426	0.426

Note: Below CRS of 4.0, the models are estimated.

Figure 9 shows the current and proposed standard models for Districts 1 through 4 and Figure 10 shows the current and proposed standard models for Districts 5 through 9. Although the proposed models for both Districts 1 through 4 and Districts 5 through 9 are similar to the current models above a CRS of 5.5, the proposed models below CRS 5.5 predict slower deterioration for the AC/JRCPs and faster deterioration for the AC/HJCPs.

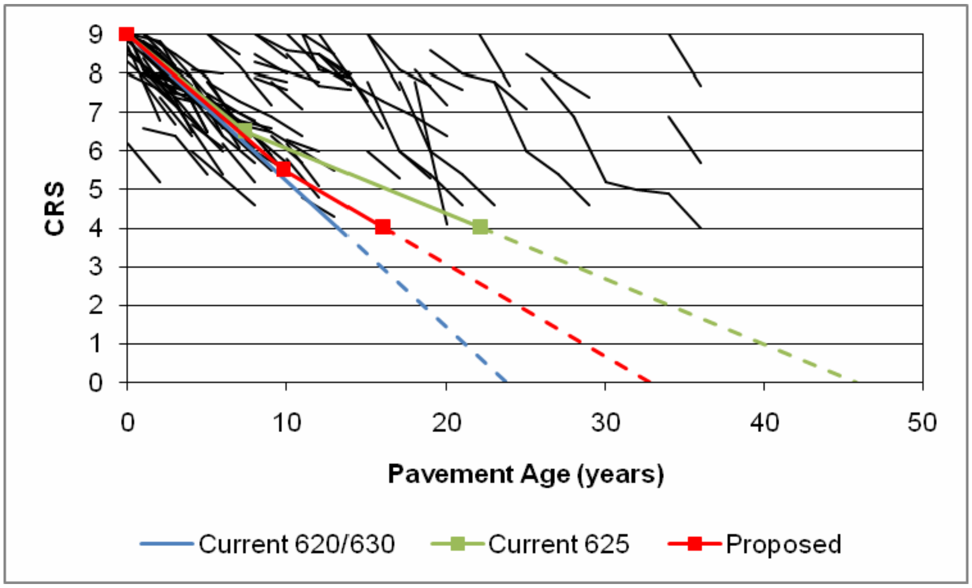

Figure 9. Interstate AC/HJCP and AC/JRCP, districts 1 through 4.

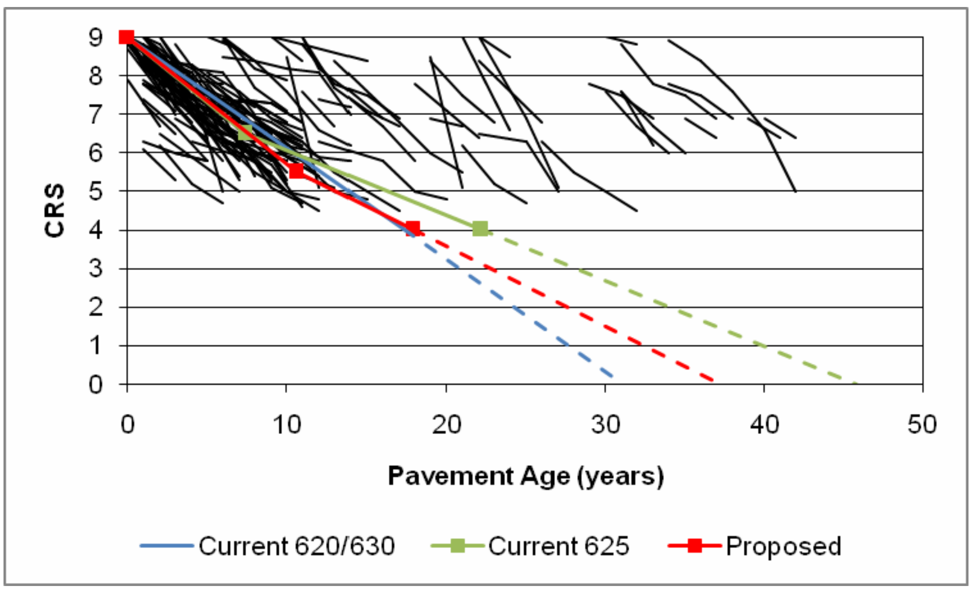

Figure 10. Interstate AC/HJCP and AC/JRCP, districts 5 through 9.

Figure 11 shows the model for SMART projects on these two pavement types. The proposed model is much steeper between CRS 9.0 and CRS 5.5, but shallower below CRS 5.5. The limited amount of data causes more variation between the current and proposed models.

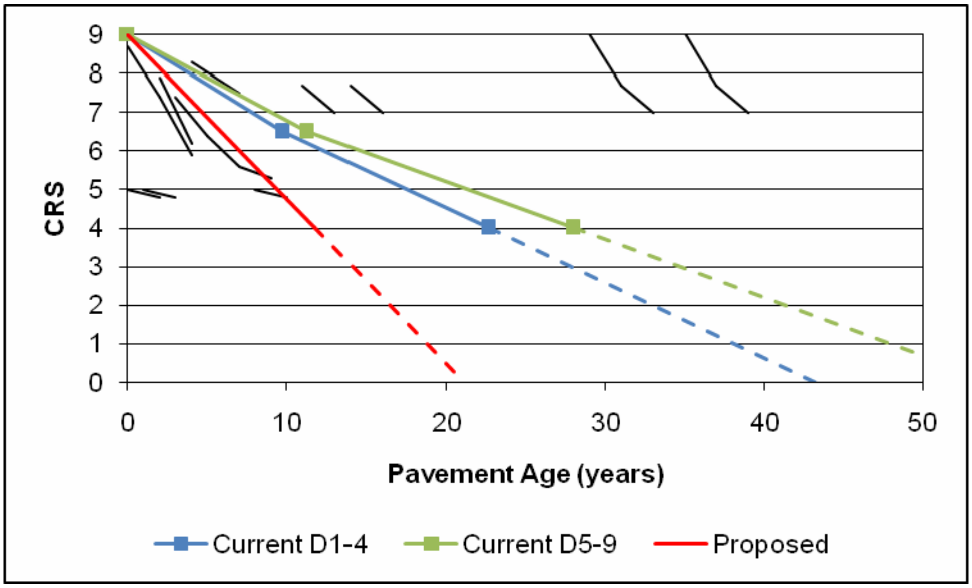

Figure 11. SMART interstate AC/HJCP and AC/JRCP, all districts.

The number of years for the models to reach CRS values of 4.5 are listed in Table 9 and Table 10. For asphalt overlays of hinge-jointed pavements, the standard and SMART models predict shorter lives for the pavements. The D-cracking model in the southern districts predicts longer life than the current models. For jointed reinforced concrete pavements, the proposed models predict a longer life for standard pavements and D-cracking pavements in the northern districts, and shorter life for D-cracking pavements in the southern districts as well as SMART projects in all districts.

Table 9. Interstate AC/HJCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	16.2	14.0
	5 – 9	16.2	15.4
D-Cracking	1 – 4	16.2	14.0
	5 – 9	7.7	9.2
SMART	1 – 4	20.0	10.6
	5 – 9	24.6	10.6

Table 10. Interstate AC/JRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	11.9	14.0
	5 – 9	15.6	15.4
D-Cracking	1 – 4	11.9	14.0
	5 – 9	12.5	9.2
SMART	1 – 4	20.0	10.6
	5 – 9	24.6	10.6

4.4 INTERSTATE AC/CRCP

Table 11 contains the current and proposed models for this pavement type. Because there is very little below a break point of 5.5, no break point is used. Except for the D-cracking model for Districts 5 through 9, all D-cracking and SMART models predicted similar or slightly better performance than the standard model. Therefore, standard model is recommended for use in those instances.

Table 11. Interstate AC/CRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.354	0.354	0.356	0.356
	5 – 9	0.322	0.322	0.270	0.270
D-Cracking	1 – 4	0.443	0.443	0.356	0.356
	5 – 9	0.403	0.403	0.395	0.395
SMART	1 – 4	0.231	0.231	0.356	0.356
	5 – 9	0.231	0.231	0.270	0.270

Note: Below CRS of 4.0, the models are estimated.

Figure 12 shows the current and proposed standard models for Districts 1 through 4, with the data used for development. The proposed model is virtually identical to the current model.

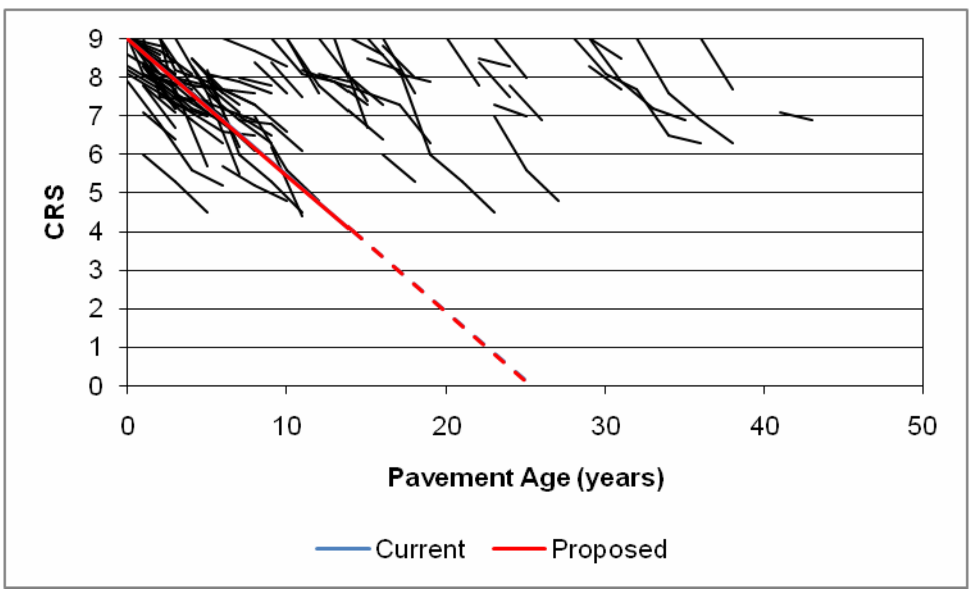

Figure 12. Interstate AC/CRCP, districts 1 through 4.

Figure 13 shows the current and proposed standard models for Districts 5 through 9, with the data used for development. The proposed model predicts slightly slower deterioration than the current model.

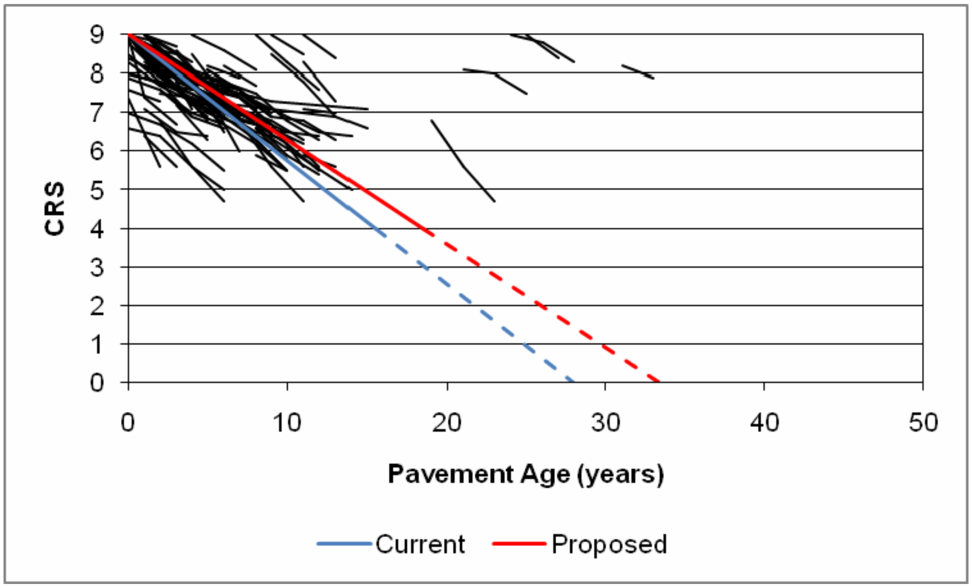

Figure 13. Interstate AC/CRCP, districts 5 through 9.

Figure 14 shows the data used for D-cracking model development, as well as the current and proposed models, in Districts 5 through 9. Again, the proposed model is almost identical to the current model.

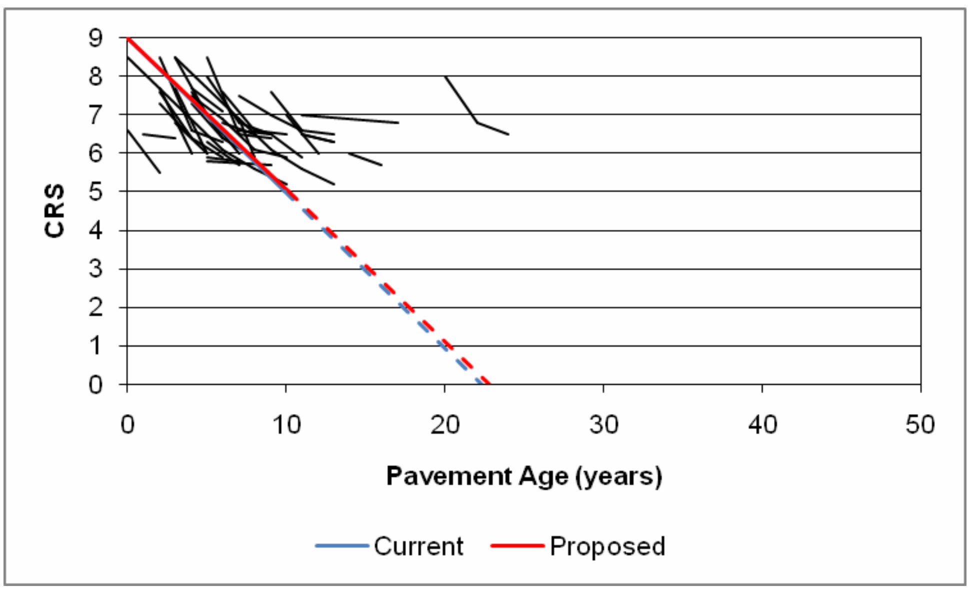

Figure 14. D-cracking interstate AC/CRCP, districts 5 through 9.

The amount of time in years elapsed for the CRS to reach values of 4.5 are detailed in Table 12. Most proposed models predict pavement lifespan similar to the current models. However, the proposed SMART model in the northern districts predicts a shorter lifespan.

Table 12. Interstate AC/CRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	12.7	12.6
	5 – 9	14.0	16.7
D-Cracking	1 – 4	10.2	12.6
	5 – 9	11.2	11.4
SMART	1 – 4	19.5	12.6
	5 – 9	19.5	16.7

4.5 INTERSTATE HJCP

Very few HJCP projects have been constructed on the interstate system. Table 13 contains the current and proposed models for this pavement type. No SMART model is needed for bare concrete pavements.

Table 13. Interstate HJCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.109	0.109	0.140	0.140
D-Cracking	1 – 9	0.338	0.338	Use JRCP D-cracking Model	

Note: Below CRS of 8.0, the models are estimated.

Figure 15 shows the data used for model development, the current standard model, and the proposed standard model. Note the few traces, and that they are at a very high CRS level. The model is accurate for the few projects in existence. Extrapolating the models below a CRS of 8.0 is not recommended. As the projects deteriorate, the standard model should be revised to accurately reflect field performance of this pavement type.

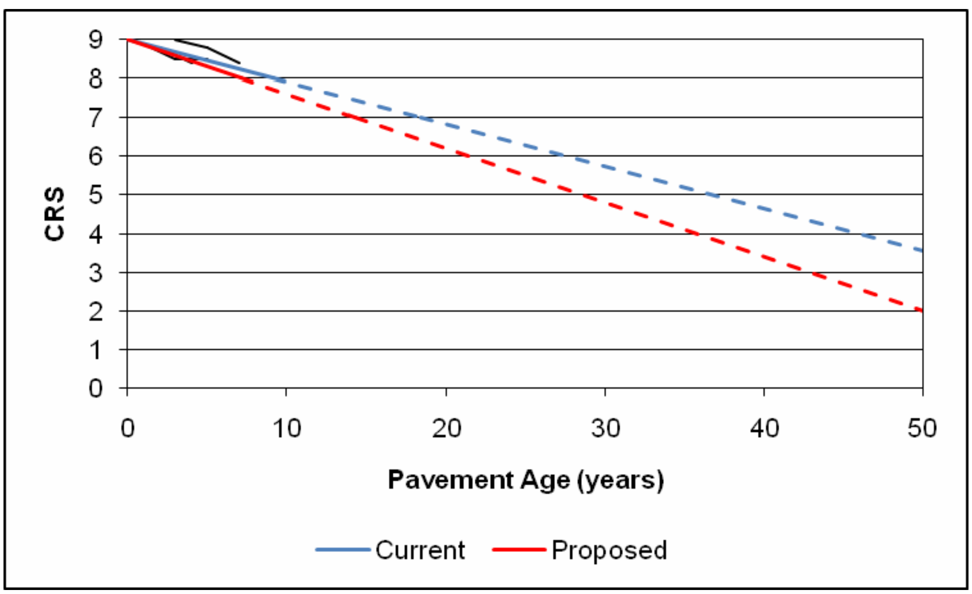

Figure 15. Interstate HJCP, all districts.

Table 14 contains the number of years required for the models to reach CRS values of 4.5. Shorter lives are predicted for standard concrete pavements, while longer lives are predicted for D-cracked pavements.

Table 14. Interstate HJCP Years to CRS 4.5

		Current	Proposed
Model Type	Districts	(years)	(years)
Standard	1 – 9	41.3	32.1

4.6 INTERSTATE JRCP

Table 15 details the current and proposed models for the JRCP pavement type. No SMART model is needed for bare concrete pavements.

Table 15. Interstate JRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.338	0.338	0.213	0.228
D-Cracking	1 – 9	0.338	0.338	0.225	0.225

Note: Below CRS of 4.0, the models are estimated.

The data used for model development, the current standard model, and the proposed standard model for JRCPs are all shown in Figure 16. Splitting the districts into 1 through 4 and 5 through 9 was not necessary. The proposed model predicts slower deterioration than the current model does, most likely because this pavement type is rarely, if ever, being constructed on the interstate system, and the remaining projects are the best performers of those previously constructed.

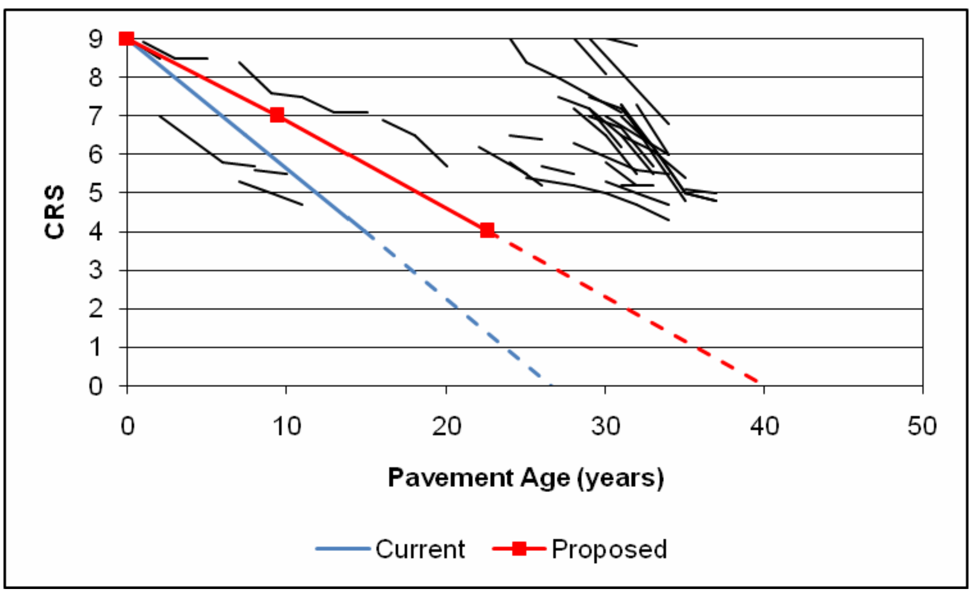

Figure 16. Interstate JRCP, all districts.

All D-cracked jointed concrete pavements were combined due to the limited amount of data. Figure 17 shows the current and proposed models, and data used in model development, for all D-cracked interstate jointed concrete pavements. The proposed model predicts slower deterioration than the current model does. Because the

D-cracking-susceptible aggregate policy has been in effect for approximately 20 years, the only remaining projects were the best performers, because the worst performers have all been rehabilitated or reconstructed. No D-cracking pavements younger than 20 years of age are anticipated. Once these few sections have been rehabilitated or reconstructed, the model may be retired.

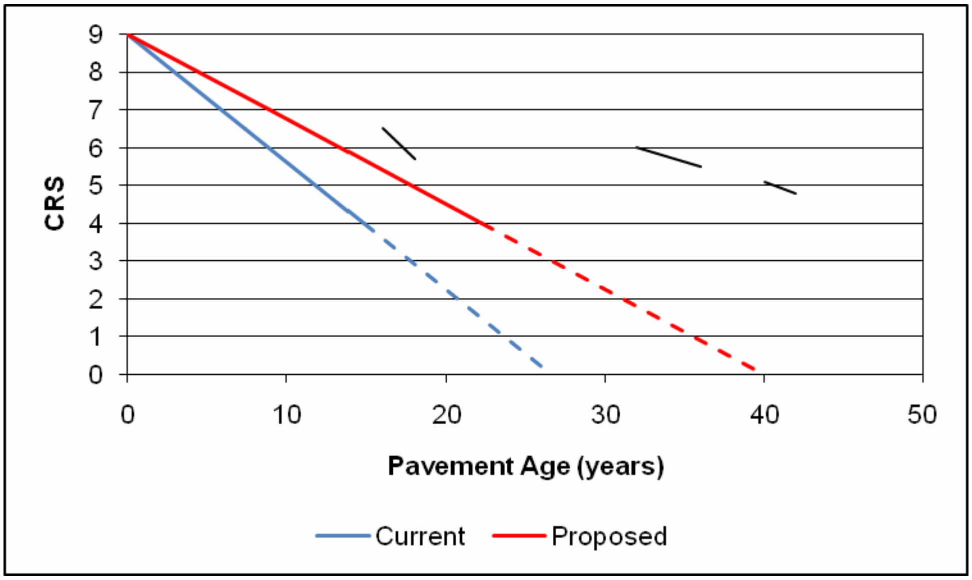

Figure 17. D-cracking interstate jointed concrete – all types and districts.

The required time for the models to reach CRS values of 4.5 are included in Table 16. The proposed models predict longer lives for both standard and D-cracked pavements.

Table 16. Interstate JRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	13.3	20.4
D-Cracking	1 – 9	13.3	20.0

4.7 INTERSTATE CRCP

The current and proposed models for interstate CRCPs are presented in Table 17. Again, there was no difference in performance between the northern and southern districts, and no SMART model is necessary.

Table 17. Interstate CRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.264	0.083	0.144	0.165
D-Cracking	1 – 9	0.264	0.083	0.203	0.203

Note: Below CRS of 5.0, the models are estimated.

Figure 18 shows the data and standard models for CRCPs. The proposed model predicts slower deterioration than the current model at CRS values above 7.0, and faster deterioration below CRS 7.0. The proposed model is much closer to the data than the current model is.

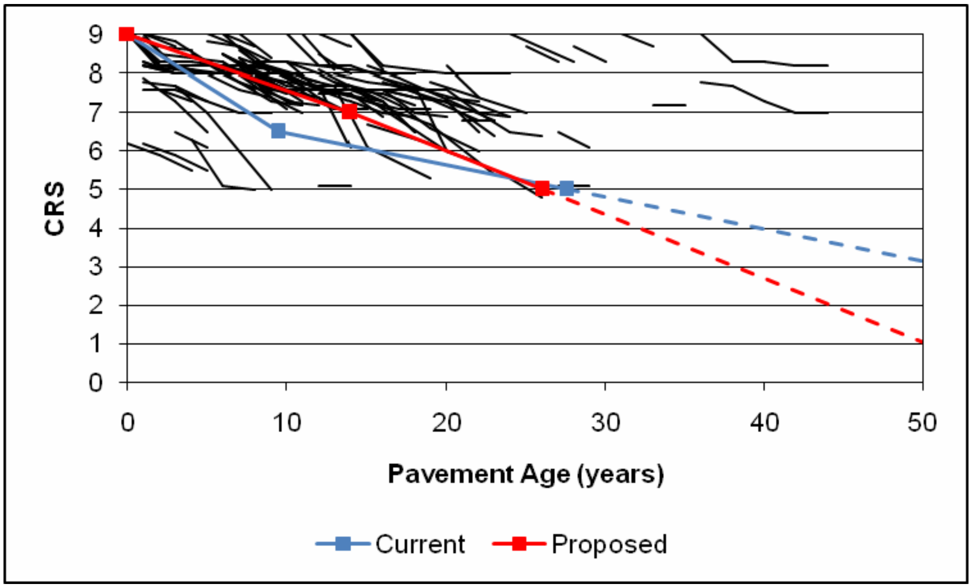

Figure 18. Interstate CRCP, all districts.

Figure 19 shows the models for D-cracking CRCPs. The model is similar to the current model above CRS 6.5, and predicts faster deterioration at CRS values below 6.5. While the sections at and above 20 years are most likely actual D-cracking sections, those newer than 20 years are suspect. The younger sections have either been misidentified as D-cracking, or the age information is incorrect. Again, the D-cracking policy has been in effect for approximately 20 years, so no D-cracking pavements younger than 20 years of age are anticipated.

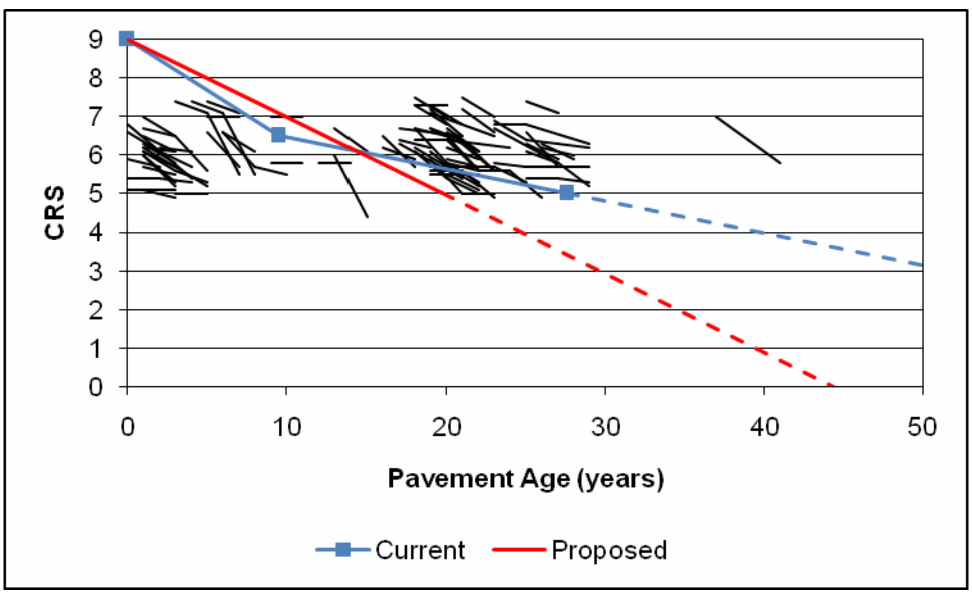

Figure 19. D-cracking interstate CRCP, all districts.

The number of years it will take the models to reach CRS values of 4.5 are included in Table 18. The proposed models predict shorter lives for both standard and D-cracked pavements.

Table 18. Interstate CRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	37.7	29.0
D-Cracking	1 – 9	33.6	22.2

4.8 INTERSTATE COMBINATION TYPE PAVEMENTS (95X, 96X, AND 97X)

Combination pavements have two or more pavement types on a single roadway section. The first number of the code, 9, indicates a combination pavement; the second number indicates the predominant pavement type; and the third number indicates the less predominant pavement type. Type 95x, therefore, has full-depth asphalt as the predominant type, with the “x” used to denote any other pavement type as the less predominant. Type 96x has asphalt over concrete pavement as the most predominant, and 97x has bare concrete as the most predominant pavement type. For deterioration model development, 95x and 96x pavements were grouped together, and 97x pavements were modeled separately.

The current and proposed models for type 95x and 96x combination pavements are shown in Table 19. There was insufficient data to develop a model for SMART projects on the interstate system.

Table 19. Interstate Combination 95x/96x Pavements Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.130	0.267	0.314	0.314
D-Cracking	1 – 4	0.130	0.267	0.388	0.388
	5 – 9	0.456	0.456	0.388	0.388

Note: Below CRS of 5.0, the models are estimated.

Figure 20 shows the data used for model development, and the current and proposed standard models. The proposed standard model predicts much faster deterioration than the current standard model does, and is located in the center of the data.

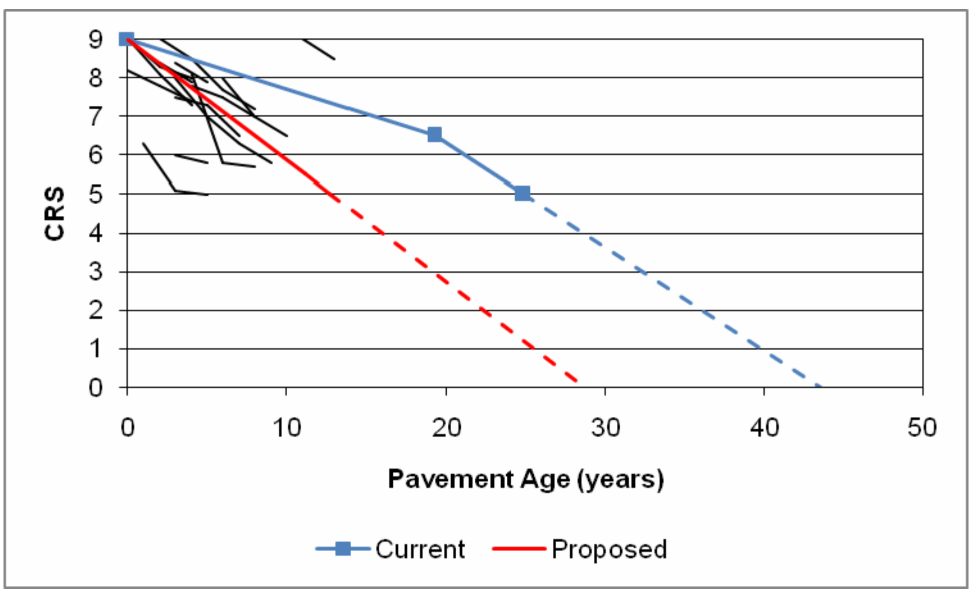

Figure 20. Interstate 95x and 96x, all districts.

A D-cracking model was developed for all combination pavements on the interstate system and is shown in Figure 21. The model should be revised if additional data become available.

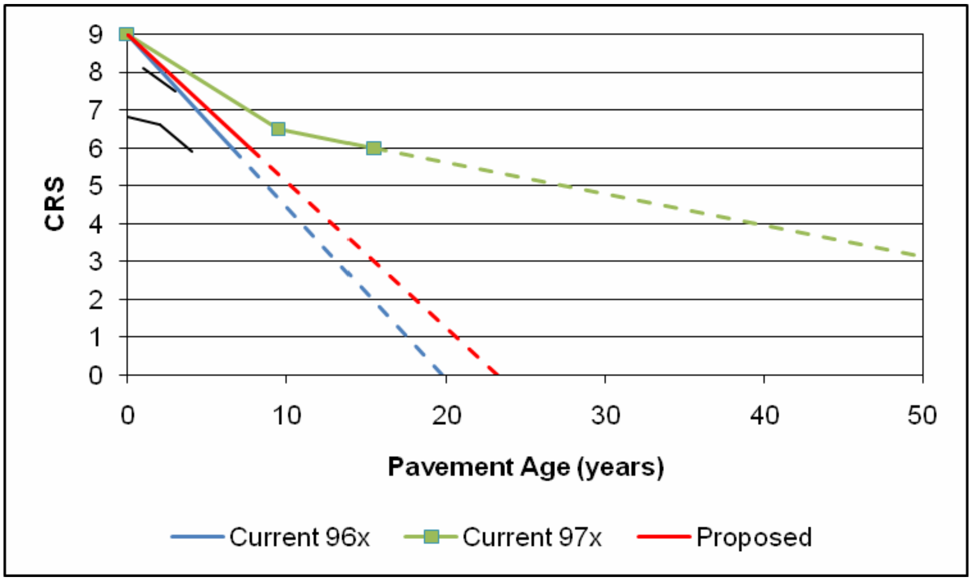

Figure 21. D-cracking interstate 9xx, all districts.

Table 20 lists the number of years to reach CRS values of 4.5. Shorter lives are predicted for standard pavements, while longer lives are predicted for D-cracking pavements.

Table 20. Interstate Combination 95x/96x Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	30.7	14.3
D-Cracking	1 – 4	30.7	14.3
	5 – 9	9.9	11.6

Table 21 contains the current and proposed models for type 97x combination pavements. Grouping the districts into northern and southern areas was unnecessary, and SMART modeling is not applicable.

Table 21. Interstate Combination Type Pavements (97x) Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.264	0.083	0.221	0.248
D-Cracking	1 – 9	0.264	0.083	0.388	0.388

Note: Below CRS of 5.0, the models are estimated.

The current and proposed standard models are shown graphically in Figure 22. The two models are very similar through a CRS of 7.0, but the proposed standard model predicts faster deterioration below a CRS of 7.0.

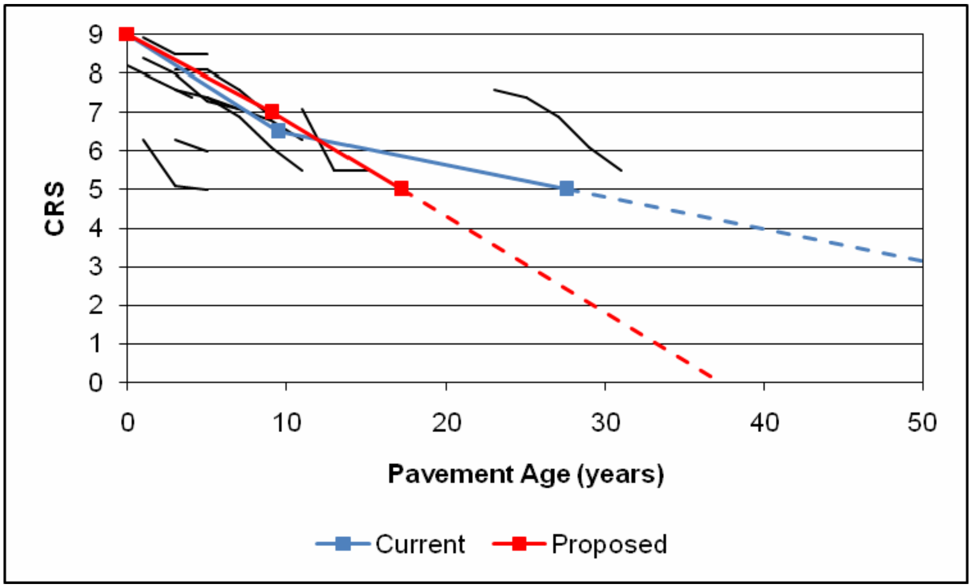

Figure 22. Interstate 97x, all districts.

The number of years to reach CRS values of 4.5 are detailed in Table 22. Shorter lives are predicted for both standard and D-cracking concrete pavements.

Table 22. Interstate Combination 97x Years to CRS 4.5

		Current	Proposed
Model Type	Districts	(years)	(years)
Standard	1 – 9	37.7	19.1
D-Cracking	1 – 9	33.6	11.6

4.9 NON-INTERSTATE ACSTLT

There currently are no models for this pavement type. Most sections are on the unmarked system. Table 23 shows the proposed model. D-cracking is not applicable to this pavement type, and no SMART projects have been constructed.

Table 23. Non-Interstate ACSTLT Models

		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.451	0.451

Figure 23 shows the data and proposed standard model for this pavement type.

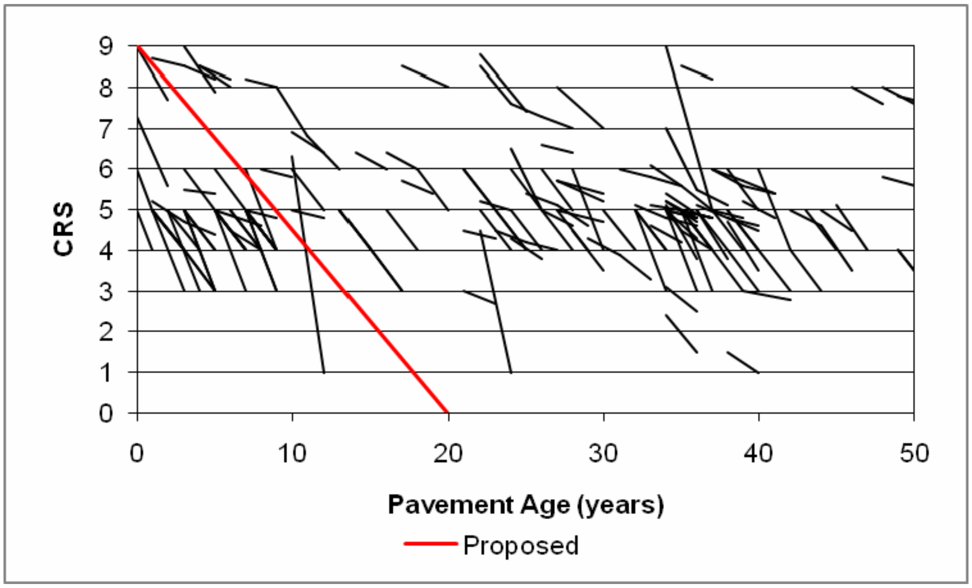

Figure 23. Non-interstate ACSTLT, all districts.

Table 24 shows the number of years until the predicted CRS equals 4.5. As there currently are no models, no comparison can be made.

Table 24. Non-Interstate ACSTLT Years to CRS 4.5

		Proposed
Model Type	Districts	(years)
Standard	1 – 9	10.0

4.10 NON-INTERSTATE ACPLT

There currently are no models for this pavement type. D-cracking is not applicable. A SMART model was developed based on the few sections that have been constructed. The models are detailed in Table 25.

Table 25. Non-Interstate ACPLT Models

		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.374	0.374
SMART	1 – 9	0.388	0.388

Note: Below CRS of 2.0, the models are estimated.

Figure 24 shows the data and proposed standard model.

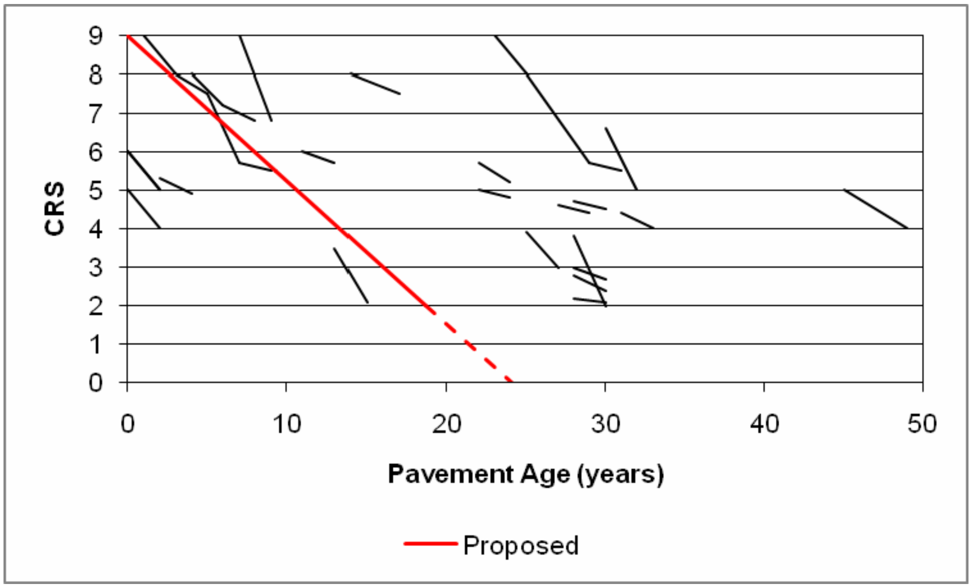

Figure 24. Non-interstate ACPLT, all districts.

Figure 25 shows the SMART model for ACPLTs. The model should be revised if more data becomes available.

Figure 25. SMART non-interstate ACPLT, all districts.

The number of years until the CRS of this pavement type reaches 4.5 are shown in Table 26. Again, because there are no current models, there can be no comparison.

Table 26. Non-Interstate ACPLT Years to CRS 4.5

Model Type	Districts	Proposed (years)
Standard	1 – 9	12.0
SMART	1 – 9	11.6

4.11 NON-INTERSTATE ACSTHT

Table 27 shows the current and proposed models for this pavement type. D-cracking is not applicable.

Table 27. Non-Interstate ACSTHT Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.281	0.281	0.322	0.248
SMART	1 – 9	0.281	0.281	0.367	0. 367

In Figure 26, the data and current and proposed standard models are shown. The current and proposed models are virtually identical.

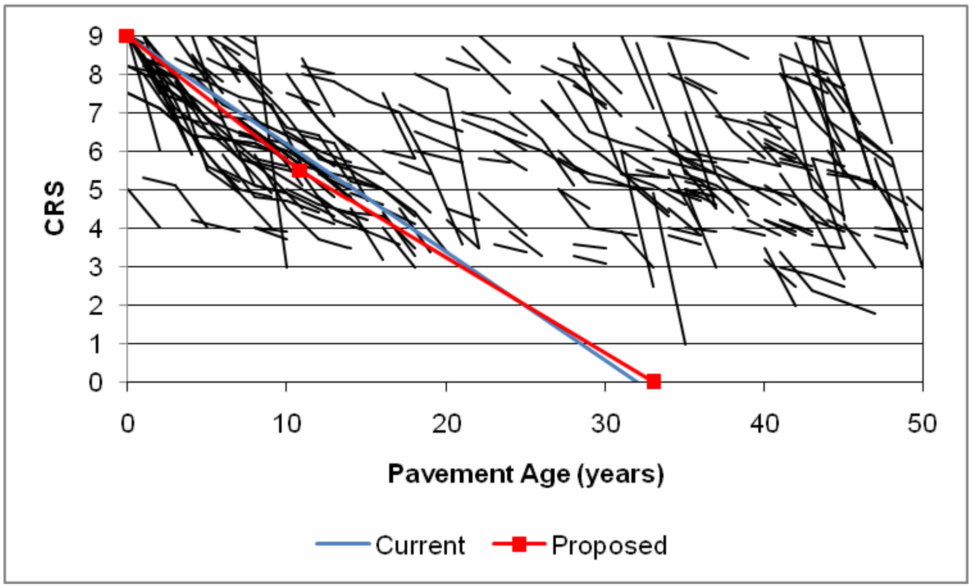

Figure 26. Non-interstate ACSTHT, all districts.

A deterioration model was created for SMART projects, although there were very few traces for use in model development. The model is shown graphically in Figure 27. The proposed model predicts faster deterioration than the current model. Again, the model should be revised if more data become available.

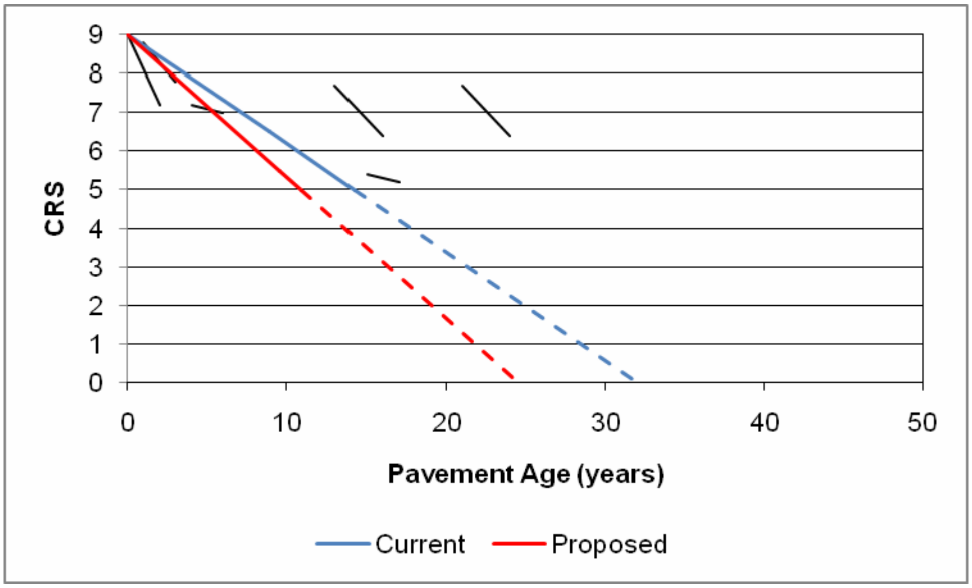

Figure 27. SMART non-interstate ACSTHT, all districts.

Table 28 contains the number of years that elapse before the CRS values reach 4.5. Standard pavements are predicted to last longer and SMART pavements are expected to last a shorter amount of time using the new models.

Table 28. Non-interstate ACSTHT Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	16.0	14.9
SMART	1 – 9	16.0	12.3

4.12 NON-INTERSTATE AC/RUBB

The models for asphalt overlays of jointed reinforced concrete pavements are currently used for asphalt overlays of rubblized concrete pavements. Asphalt overlays of rubblized concrete pavements are expected to perform more similarly to full-depth asphalt pavements. Therefore, AC/JRCP models should not be used. D-cracking is not applicable to rubblized concrete. There have been no SMART projects performed on this pavement type. Table 29 shows the proposed model, developed using only AC/Rubb data.

Table 29. Non-Interstate AC/Rubb Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.345	0.292	0.825	0.825
	5 – 9	0.260	0.150	0.825	0.825

Note: Below CRS of 5.0, the models are estimated.

Figure 28 shows the data and current and proposed standard models graphically. Because of the limited amount of data, this model should be revised as additional data become available. Because of the limited amount of data, the results reflect the individual projects' performance, not necessarily how that type of project would perform throughout the state over a longer time period.

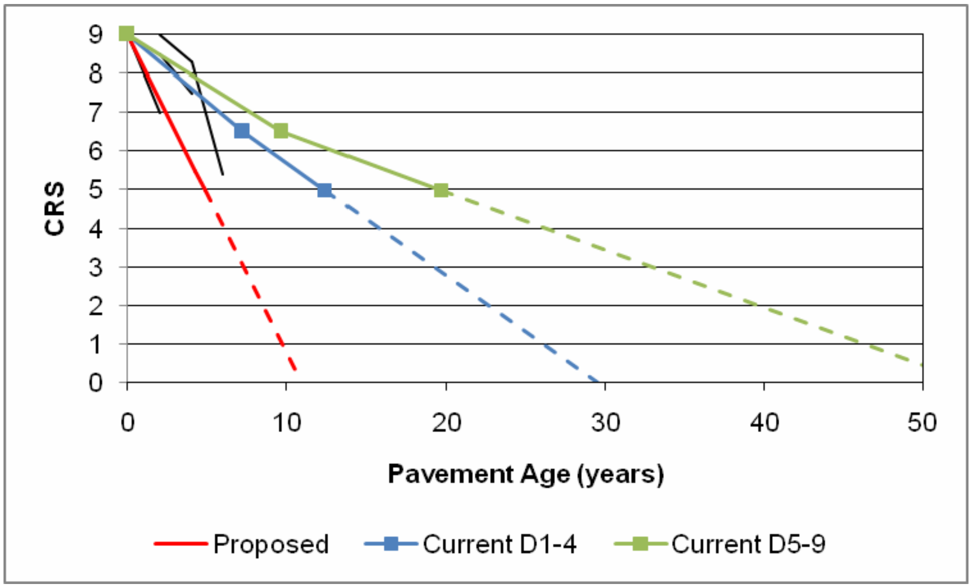

Figure 28. Non-interstate AC/Rubb, all districts.

In Table 30, the number of years until the CRS values reach 4.5 are listed. These models should be revised as more data become available.

Table 30. Non-interstate AC/Rubb Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	14.1	5.5
	5 – 9	22.9	5.5

4.13 NON-INTERSTATE ACP

Table 31 contains the current and proposed models for full-depth asphalt concrete pavements. Again, no D-cracking model is needed for this pavement type.

Table 31. Non-Interstate ACP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.405	0.278	0.350	0.251
	5 – 9	0.278	0.198	0.297	0.225
SMART	1 – 4	0.365	0.365	0.392	0.240
	5 – 9	0.365	0.365	0.317	0.181

Note: Below CRS of 2.0, the models are estimated.

Figure 29 and Figure 30 display the data, current standard model, and proposed standard model for the northern and southern districts. The proposed standard models are quite similar to the current standard model.

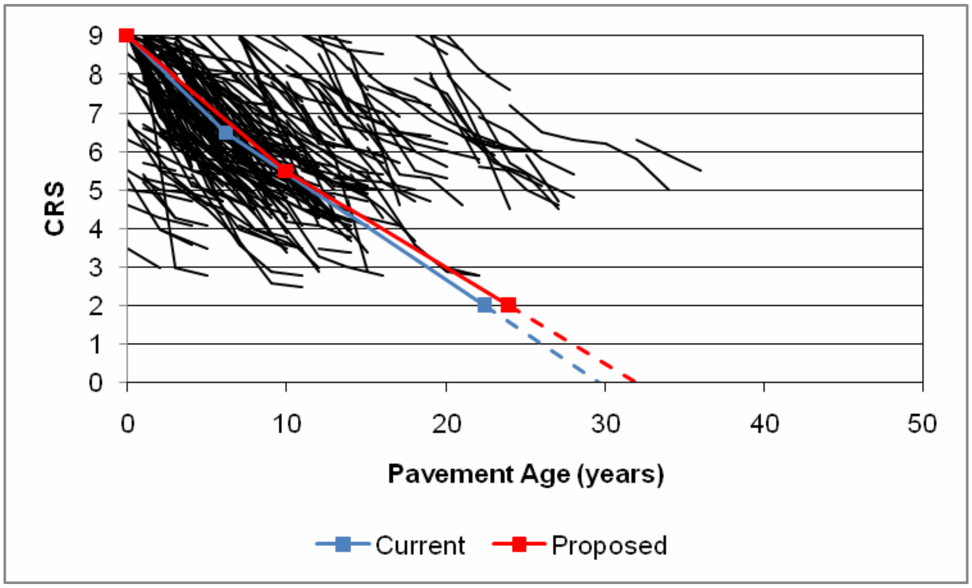

Figure 29. Non-interstate ACP, districts 1 through 4.

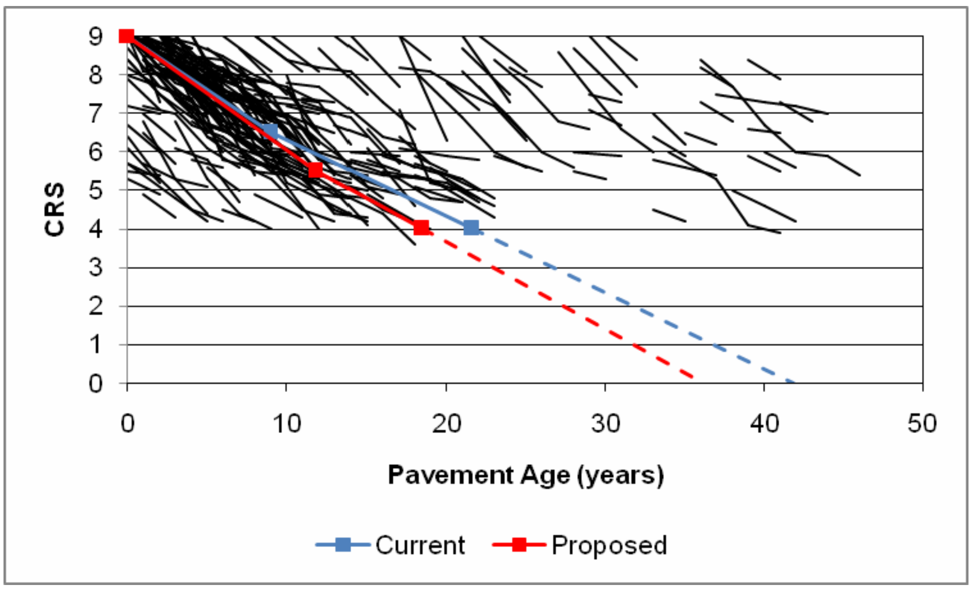

Figure 30. Non-interstate ACP, districts 5 through 9.

The SMART models are shown in Figure 31 for Districts 1 through 4 and in Figure 32 for Districts 5 through 9. The proposed models are nearly identical to the current models through CRS 5.5, but anticipate slower deterioration below that CRS level than the current models.

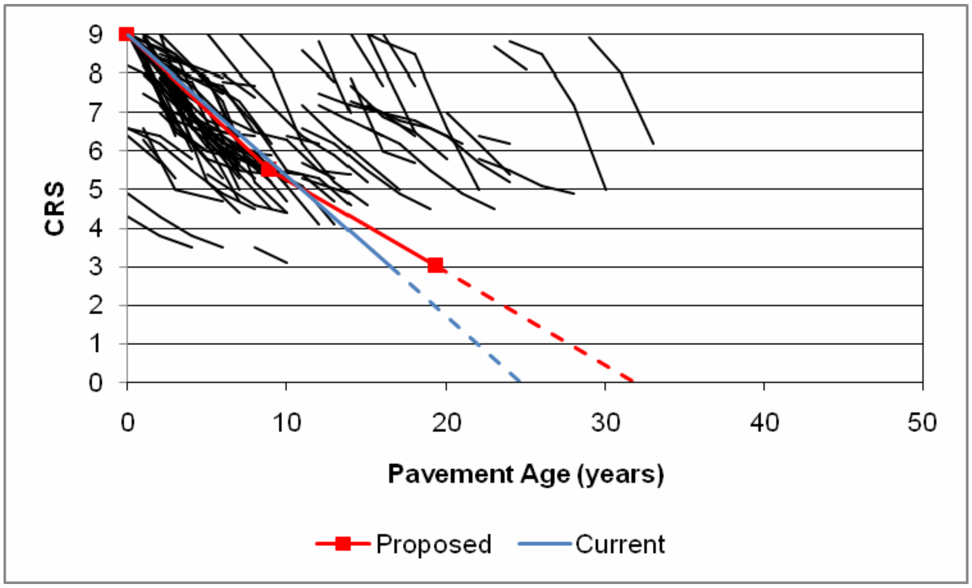

Figure 31. SMART non-interstate ACP, districts 1 through 4.

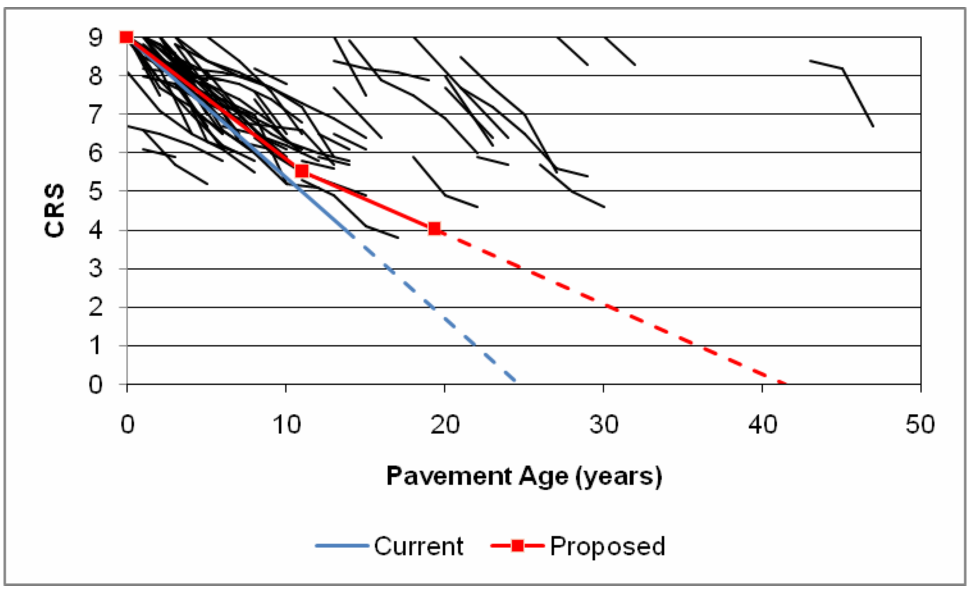

Figure 32. SMART non-interstate ACP, districts 5 through 9.

Table 32 details the number of years for these models to reach CRS values of 4.5. Standard pavements are predicted to last a slightly longer or shorter amount of time, depending on the district. SMART projects are predicted to last longer, regardless of district.

Table 32. Non-interstate ACP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	13.4	14.0
	5 – 9	19.1	16.2
SMART	1 – 4	12.3	13.1
	5 – 9	12.3	16.7

4.14 NON-INTERSTATE AC/PCCun

The current and proposed models are detailed in Table 33. For standard and D-cracking models, dividing the data into Districts 1 through 4 and 5 through 9 did not improve accuracy. The D-cracking model was developed from all asphalt overlays of all concrete pavements.

Table 33. Non-Interstate AC/PCCun Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.298	0.208	0.293	0.181
	5 – 9	0.298	0.208	0.293	0.181
D-Cracking	1 – 4	0.298	0.208	0.353	0.353
	5 – 9	0.456	0.456	0.353	0.353
SMART	1 – 4	0.440	0.219	0.329	0.175
	5 – 9	0.325	0.204	0.329	0.175

Note: Below CRS of 3.0, the models are estimated.

Figure 33 shows the data and current and proposed standard models for asphalt overlays of concrete pavements with unknown reinforcement. The proposed model is nearly identical to the current model through a CRS of 5.5, and predicts slightly slower deterioration below a CRS of 5.5.

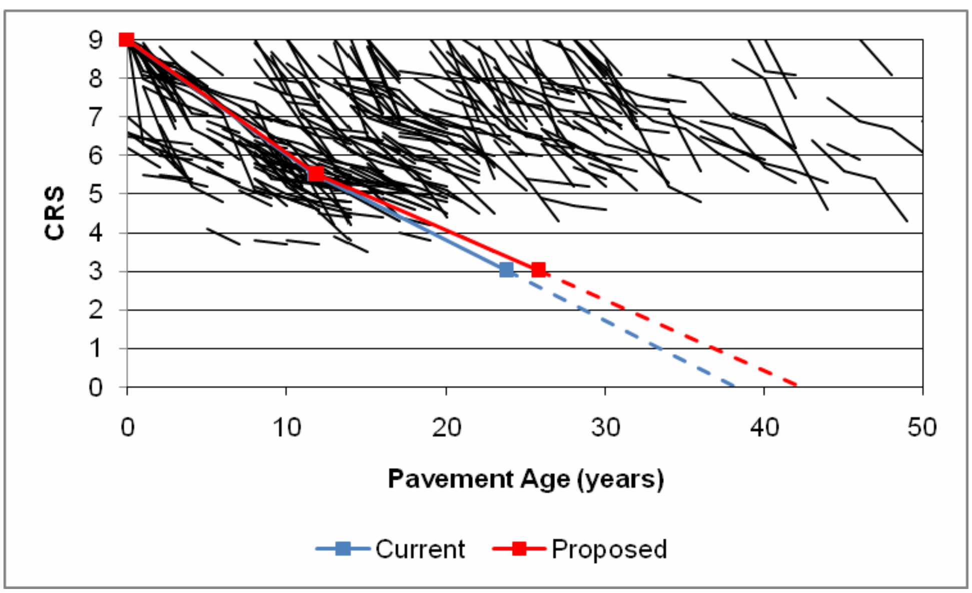

Figure 33. Non-interstate AC/PCCun, all districts.

Figure 34 shows the model for all asphalt overlays of D-cracking concrete pavements in all districts. The graph is presented in this section, and is not repeated for the remaining asphalt overlays. The current D-cracking models for asphalt overlays of concrete pavements use the standard models for Districts 1 through 4. Therefore, only the District 5 through 9 current model is shown on the graph. This is the same for all pavement types covered by the proposed D-cracking model. The proposed D-cracking model predicts slightly slower deterioration than the current model.

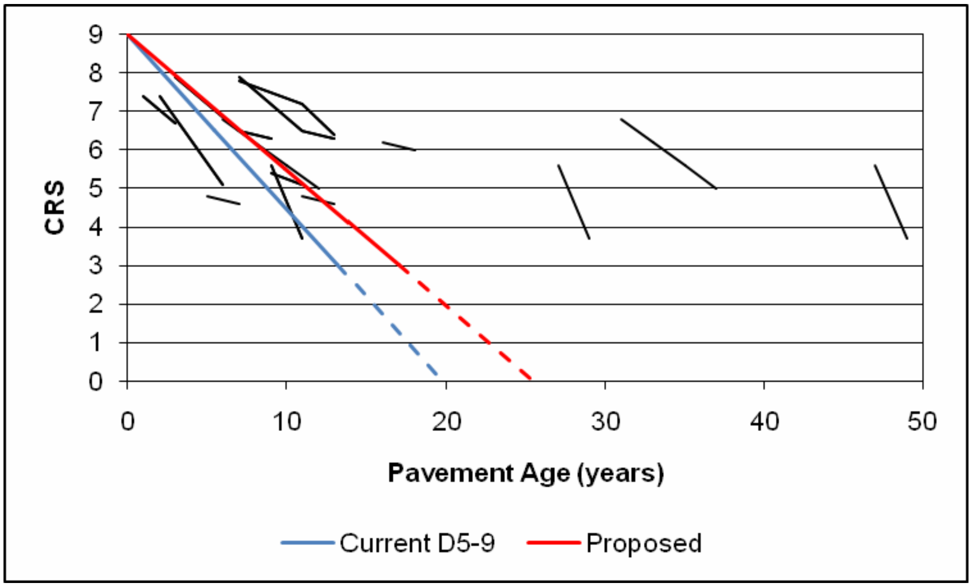

Figure 34. D-cracking non-interstate AC/all concrete, all districts.

The data, current models, and proposed SMART model for all districts are shown in Figure 35. The proposed model is similar to the current models through a CRS of 5.5, and predicts slower deterioration below that CRS level.

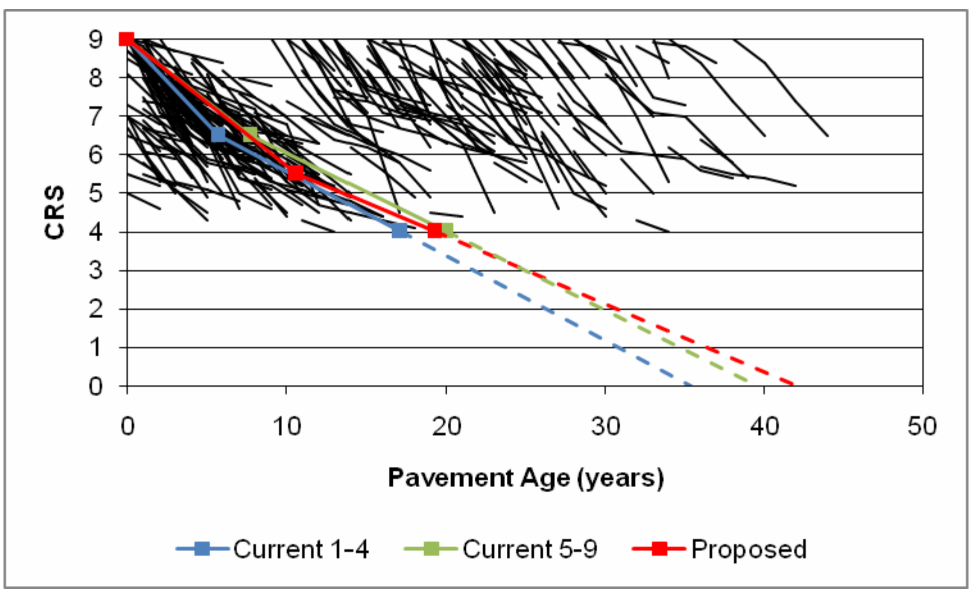

Figure 35. SMART non-interstate AC/PCCun.

The number of years until the models reach CRS values of 4.5 are included in Table 35. Except for SMART projects in the northern area of the state, all pavements are predicted to last a similar amount of time using the proposed models as compared to the current models. Northern district SMART projects are predicted to last longer than the current models.

Table 34. Non-interstate AC/PCCun Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	16.6	17.5
	5 – 9	16.6	17.5
D-cracking	1 – 4	16.6	12.7
	5 – 9	12.7	12.7
SMART	1 – 4	14.8	16.4
	5 – 9	17.5	16.4

4.15 NON-INTERSTATE AC/JPCP

Table 35 lists the current and proposed models for this pavement type.

Table 35. Non-Interstate AC/JPCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.412	0.237	0.382	0.244
	5 – 9	0.248	0.167	0.303	0.203
D-Cracking	1 – 4	0.412	0.237	0.353	0.353
	5 – 9	0.456	0.456	0.353	0.353
SMART	1 – 4	0.359	0.235	0.392	0.240
	5 – 9	0.254	0.157	0.317	0.181

Note: Below CRS of 2.0, the models are estimated.

Figure 36 shows the current and proposed standard models for Districts 1 through 4. The models are nearly identical.

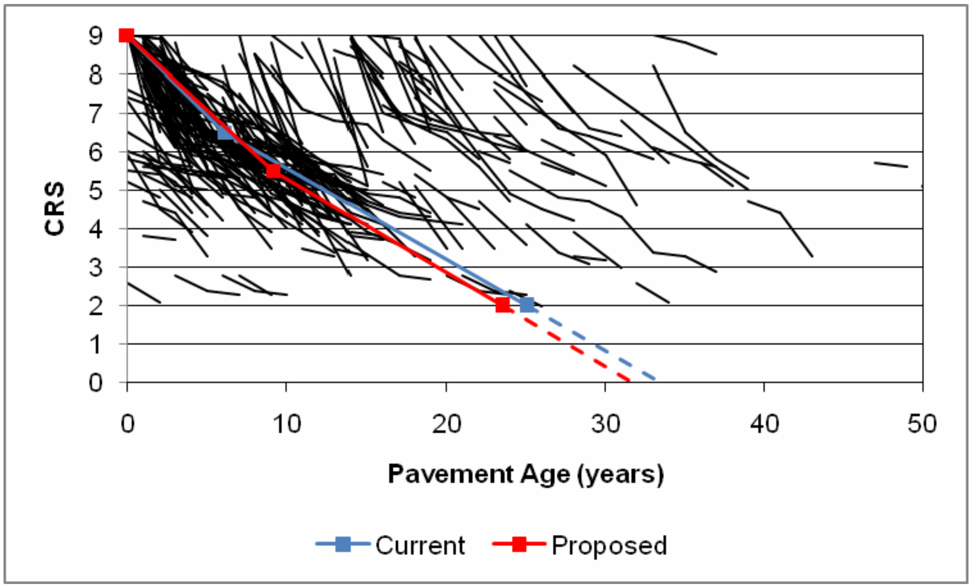

Figure 36. Non-interstate AC/JPCP, districts 1 through 4.

Figure 37 shows the data, current standard model, and proposed standard model for Districts 5 through 9. The proposed model is steeper throughout the CRS range and more closely approximates the data.

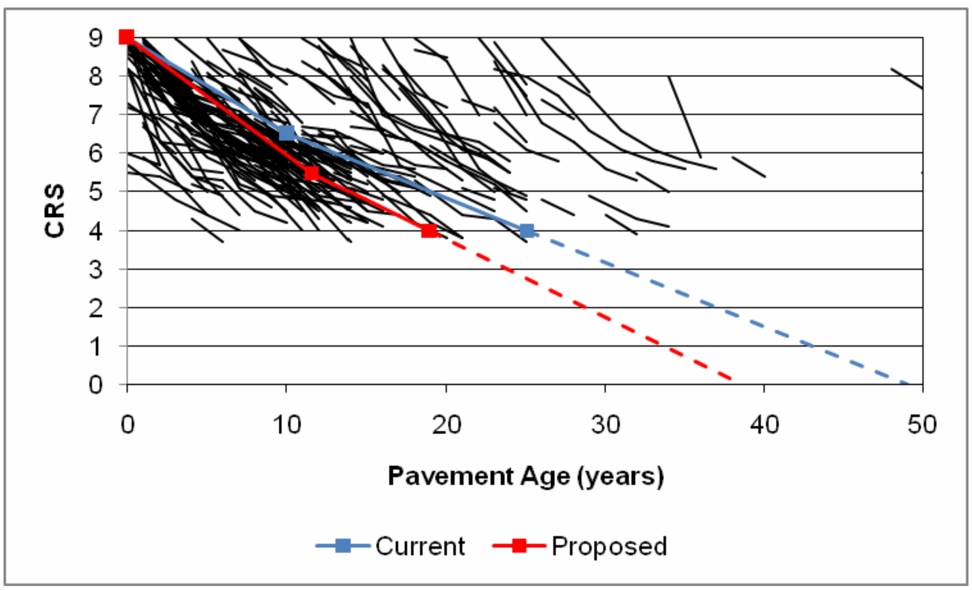

Figure 37. Non-interstate AC/JPCP, districts 5 through 9.

Figure 38 and Figure 39 show the data, current, and proposed SMART models for Districts 1 through 4 and 5 through 9, respectively. Both proposed models predict faster deterioration than the current models, and more closely approximate the data.

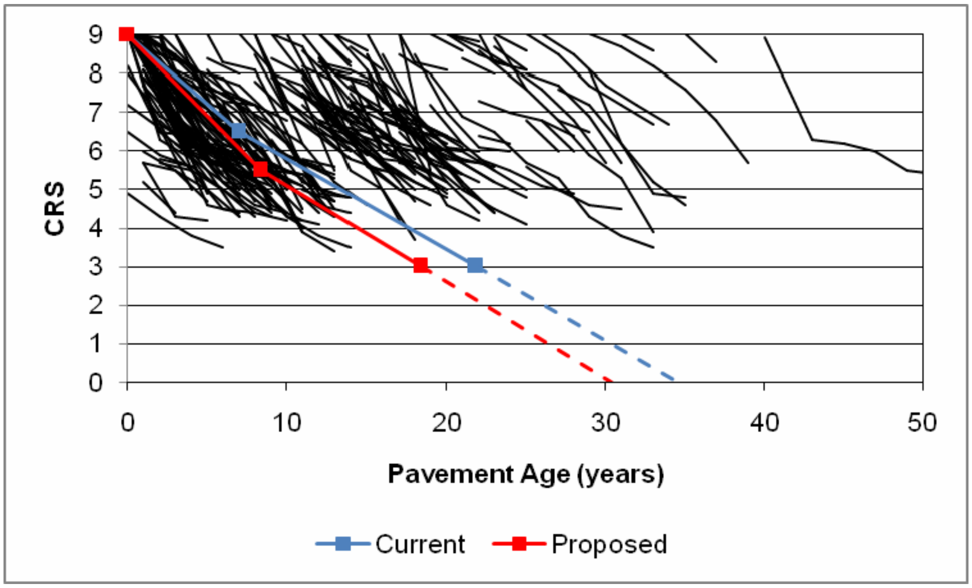

Figure 38. SMART non-interstate AC/JPCP, districts 1 through 4.

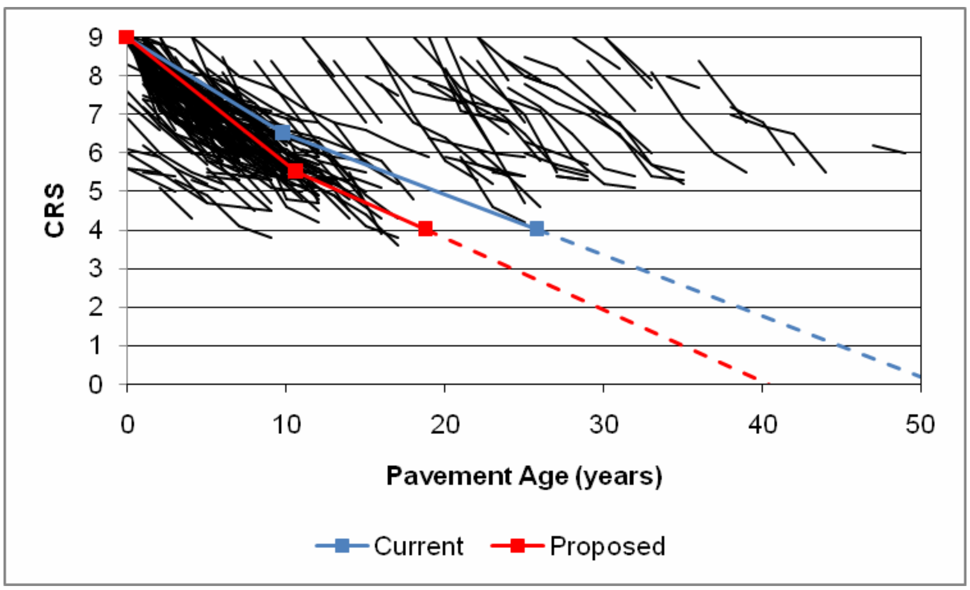

Figure 39. SMART non-interstate AC/JPCP, districts 5 through 9.

The number of years required for the CRS to reach values of 4.5 are listed in Table 36. Standard and SMART pavements in the southern districts are predicted to last a shorter amount of time using the proposed models. The remaining pavements' models are similar in lifespan.

Table 36. Non-interstate AC/JPCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	14.5	13.3
	5 – 9	22.1	16.4
D-cracking	1 – 4	14.5	12.7
	5 – 9	12.7	12.7
SMART	1 – 4	15.5	12.4
	5 – 9	22.6	16.0

4.16 NON-INTERSTATE AC/JRCP

Due to a lack of data, the asphalt overlays of hinge-jointed pavements are modeled together with asphalt overlays of concrete with partial or full reinforcement. Table 37 lists the current and proposed models for these pavement types.

Table 37. Non-Interstate AC/JRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.345	0.292	0.372	0.216
	5 – 9	0.260	0.150	0.303	0.155
D-Cracking	1 – 4	0.345	0.292	0.353	0.353
	5 – 9	0.456	0.456	0.353	0.353
SMART	1 – 4	0.257	0.194	0.417	0.236
	5 – 9	0.222	0.150	0.359	0.208

Note: Below CRS of 3.0, the models are estimated.

The data, current standard, and proposed standard models for Districts 1 through 4 and 5 through 9 are shown in Figure 40 and Figure 41, respectively. Both proposed models are similar to the current models and represent the data slightly better.

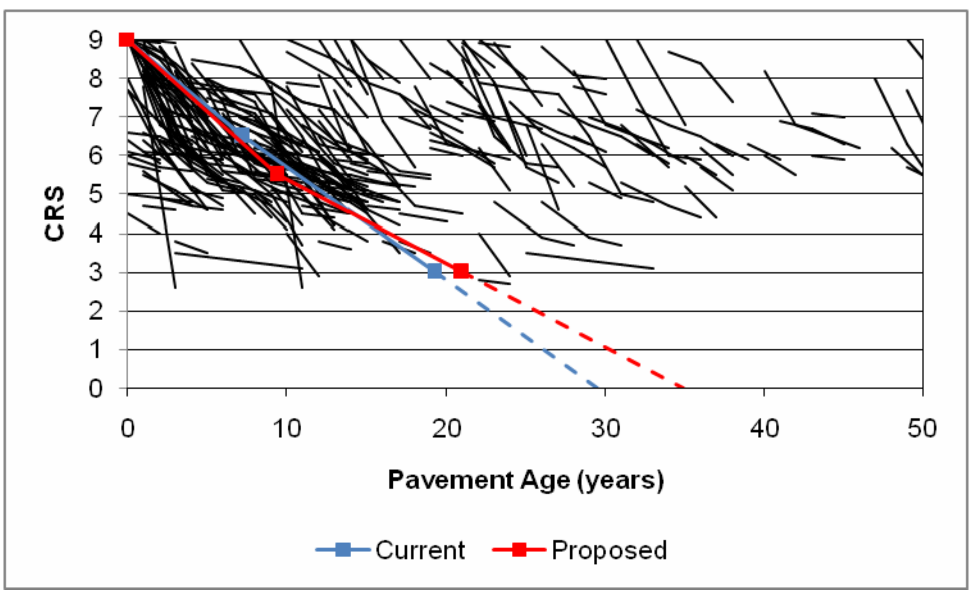

Figure 40. Non-interstate AC/JRCP, districts 1 through 4.

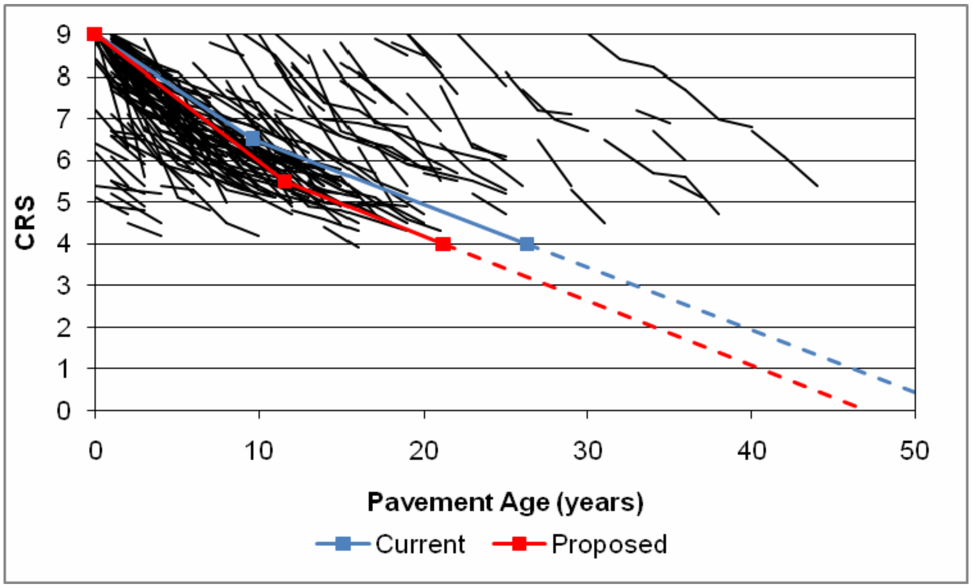

Figure 41. Non-interstate AC/JRCP, districts 5 through 9.

The SMART models for this pavement type are shown in Figure 42 and Figure 43. Both proposed models predict faster deterioration than the current models and are centered in the majority of the data.

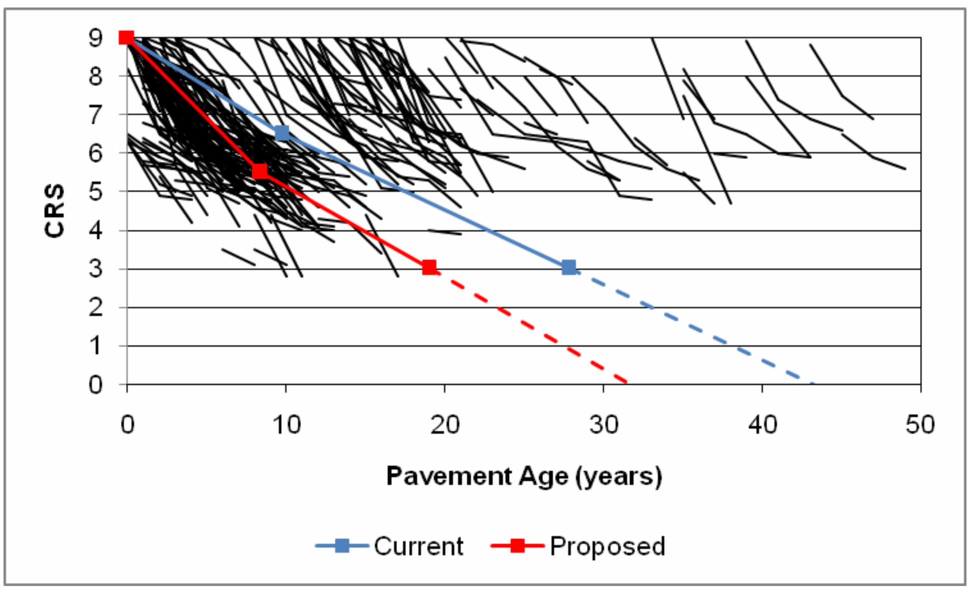

Figure 42. SMART non-interstate AC/JRCP, districts 1 through 4.

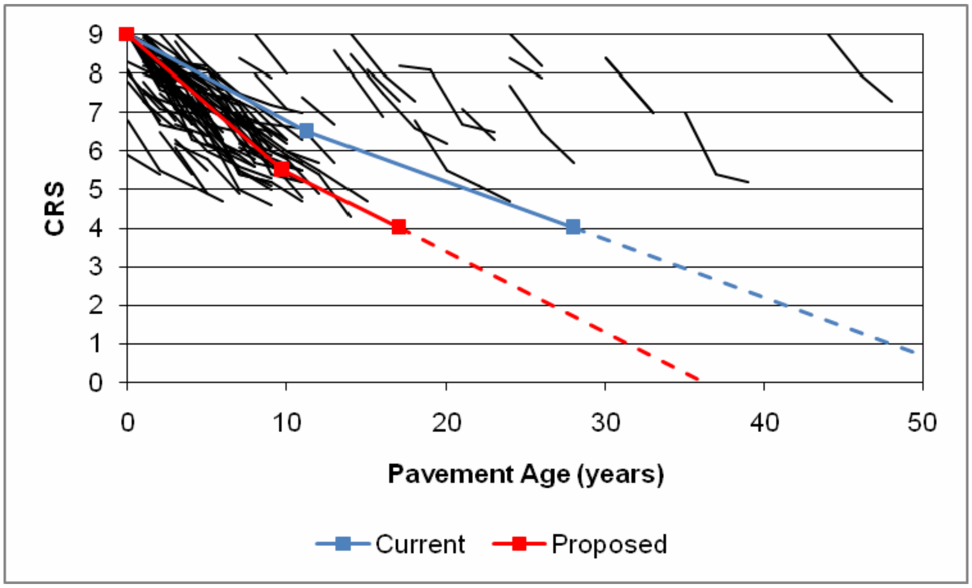

Figure 43. SMART non-interstate AC/JRCP, districts 5 through 9.

Table 38 includes the number of years required for the CRS values to reach 4.5. Standard pavements in the southern districts and all SMART projects are predicted to last a shorter time period using the proposed models, in better agreement with the data.

Table 38. Non-interstate AC/JRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	14.1	14.0
	5 – 9	22.9	18.0
D-cracking	1 – 4	14.1	12.7
	5 – 9	12.7	12.7
SMART	1 – 4	20.0	12.6
	5 – 9	24.6	14.6

4.17 NON-INTERSTATE AC/CRCP

The current and proposed models for AC/CRCPs are shown in Table 39. No division between districts was necessary. The data for SMART projects indicated better performance than their non-SMART counterparts, so the standard models are recommended for both non-SMART and SMART projects.

Table 39. Non-Interstate AC/CRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.231	0.231	0.356	0.216
D-Cracking	1 – 4	0.231	0.231	0.353	0.353
	5 – 9	0.456	0.456	0.353	0.353
SMART	1 – 9	0.231	0.231	0.356	0.216

Note: Below CRS of 4.0, the models are estimated.

Figure 44 shows the data and current and proposed standard models. The proposed model predicts faster deterioration than the current model and more closely approximates the data.

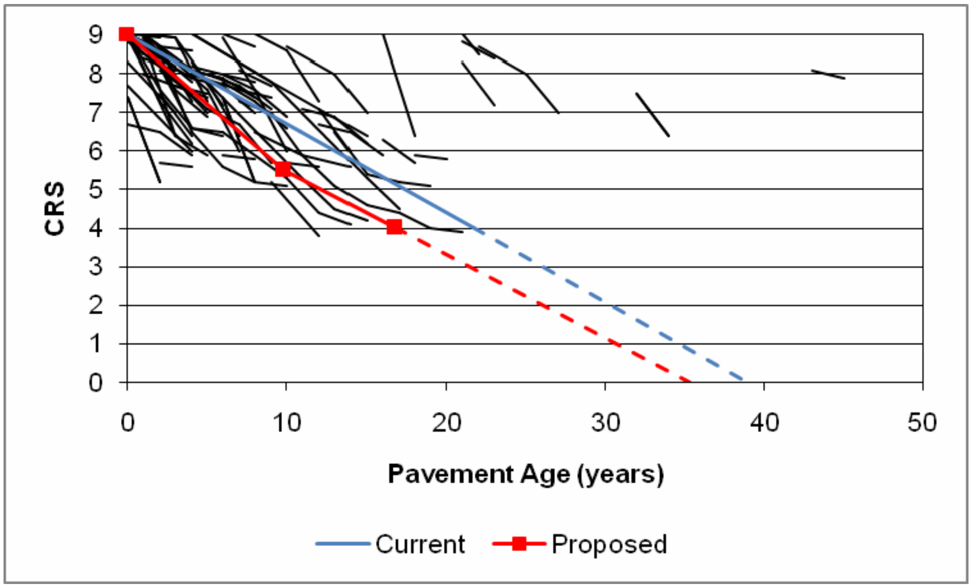

Figure 44. Non-interstate AC/CRCP, all districts.

The number of years required for the CRS values to reach 4.5 are contained in Table 40. All pavements are predicted to last a shorter amount of time, using the proposed models.

Table 40. Non-interstate AC/CRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	19.5	14.5
D-cracking	1 – 4	19.5	12.7
	5 – 9	12.7	12.7
SMART	1 – 9	19.5	15.5

4.18 NON-INTERSTATE AC/BBO

Table 41 details the current and proposed models for asphalt overlays of brick, block, or other material. While separate standard models were developed for Districts 1 through 4 and 5 through 9, the D-cracking and SMART models were modeled together because of a lack of data.

Table 41. Non-Interstate AC/BBO Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.493	0.247	0.407	0.174
	5 – 9	0.160	0.161	0.288	0.171
D-Cracking	1 – 4	0.493	0.247	0.353	0.353
	5 – 9	0.456	0.456	0.353	0.353
SMART	1 – 9	None	None	0.399	0.113

Note: Below CRS of 3.0, the models are estimated.

Figure 45 shows the current and proposed standard models for Districts 1 through 4. The two models are similar through a CRS of 5.5, and the proposed model predicts less deterioration after a CRS of 5.5.

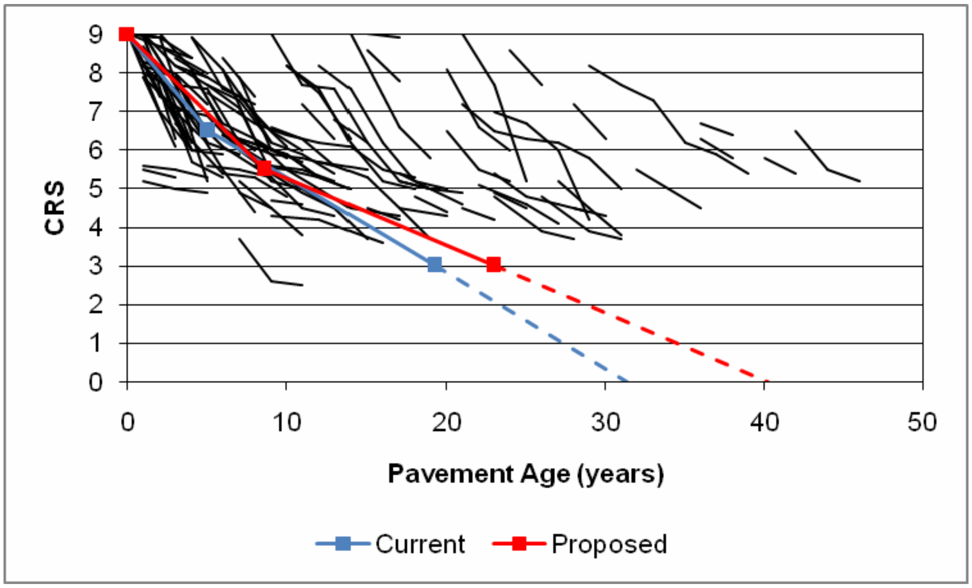

Figure 45. Non-interstate AC/BBO, districts 1 through 4.

The proposed standard model for Districts 5 through 9, shown in Figure 46, passes through the center of the most accurate data, whereas the current standard model is above the data. The proposed model predicts more rapid deterioration than the current model.

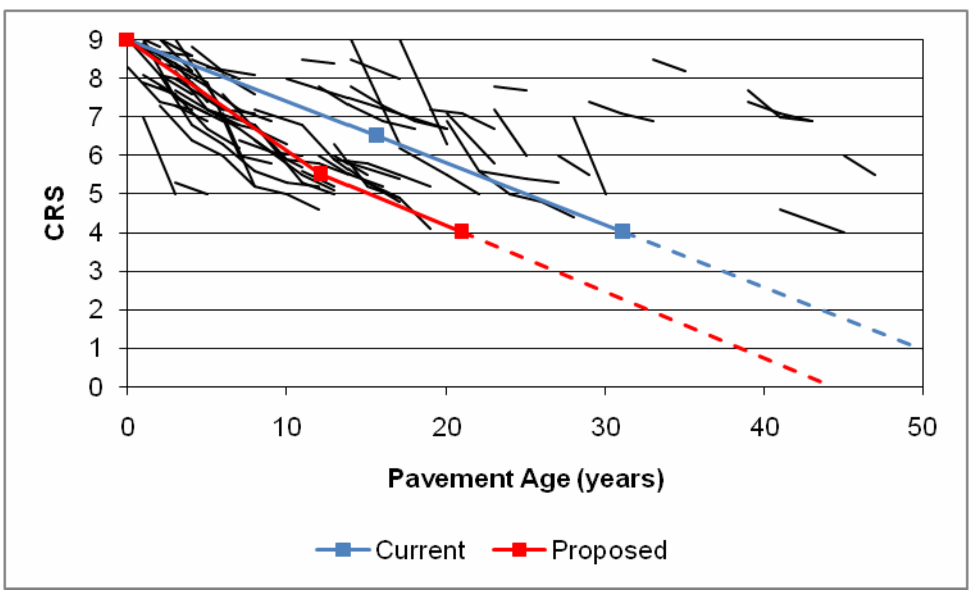

Figure 46. Non-interstate AC/BBO, districts 5 through 9.

In Figure 47, the proposed model for SMART overlays of AC/BBO is shown. It can be seen that the proposed model follows the bulk of the data. There is currently no model for SMART projects of this pavement type. The model should be revised as more data become available below a CRS of 5.0.

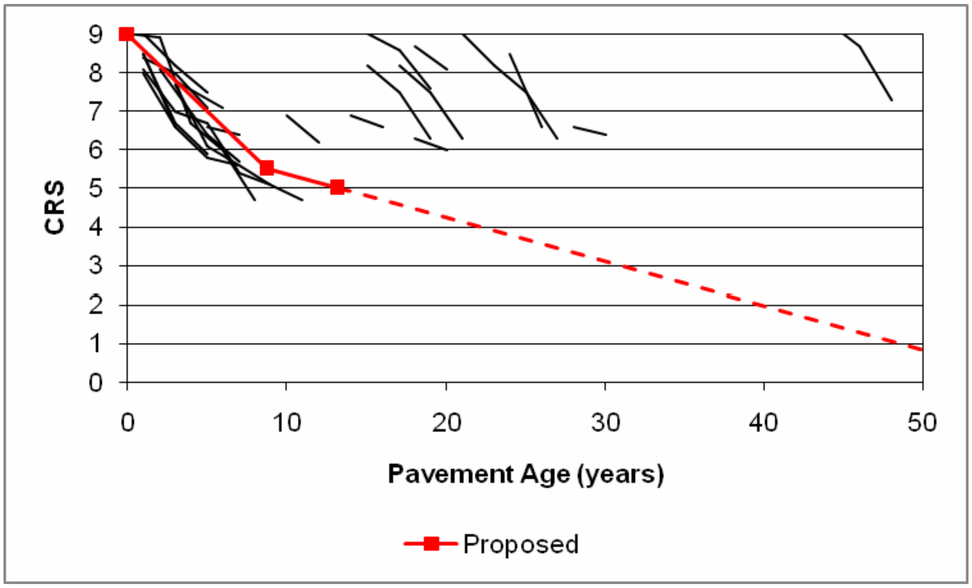

Figure 47. SMART non-interstate AC/BBO, all districts.

Table 42 lists the number of years until the CRS reaches values of 4.5. The most notable change in predicted life is seen in the southern districts, using the proposed standard model. The model represents the data much better than the current model.

Table 42. Non-interstate AC/BBO Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	13.2	14.3
	5 – 9	28.0	18.0
D-cracking	1 – 4	13.2	12.7
	5 – 9	12.7	12.7
SMART	1 – 9	None	17.6

4.19 NON-INTERSTATE PCCun

The current and proposed models for concrete pavements with unknown reinforcement are shown in Table 43. No division by district was necessary, and SMART projects do not apply.

Table 43. Non-Interstate PCCun Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.280	0.326	0.141	0.129
D-Cracking	1 – 9	0.280	0.326	0.192	0.192

Note: Below CRS of 4.0, the models are estimated.

Figure 48 shows the data, current standard, and proposed standard models. The proposed model predicts much slower deterioration than the current model and much more closely approximates the data.

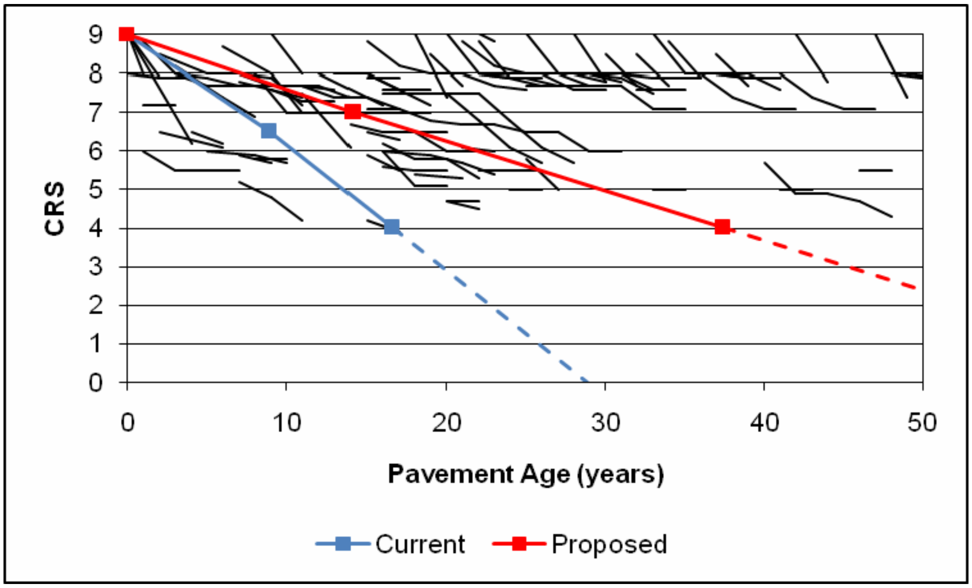

Figure 48. Non-interstate PCCun, all districts.

To have enough data for modeling, D-cracking concrete pavements with unknown reinforcement and D-cracking concrete pavements with no reinforcement were combined. The proposed model is nearly the average of the two current models. As with the interstate D-cracking concrete pavements, it is expected that the ages of these pavement sections are greater than 20 years, the length of time the policy has been used. No new D-cracking pavements are anticipated.

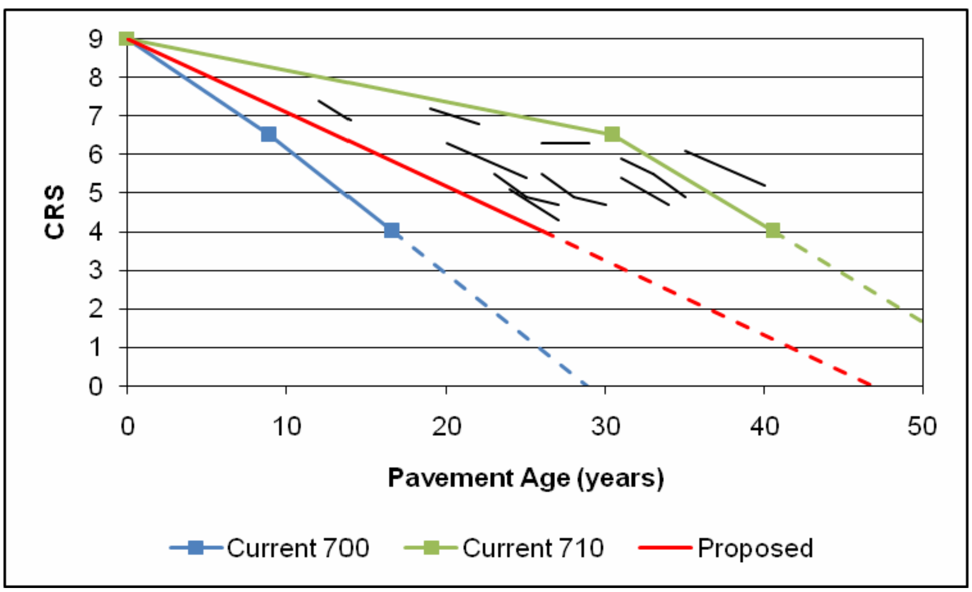

Figure 49. D-cracking non-interstate PCCun and JPCP, all districts.

The number of years until the CRS values reach 4.5 are enumerated in Table 44. All proposed models predict longer life spans than the current models, and more closely agree with the data.

Table 44. Non-interstate PCCun Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	15.1	33.6
D-cracking	1 – 9	15.1	23.4

4.20 NON-INTERSTATE JPCP

Table 45 shows the current and proposed models for concrete pavements with no reinforcement. The models were improved by dividing the data by Districts 1 through 4 and 5 through 9, and using a break point.

Table 45. Non-Interstate JPCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 4	0.082	0.249	0.184	0.190
	5 – 9	0.082	0.249	0.126	0.159
D-Cracking	1 – 9	0.082	0.249	0.192	0.192

Note: Below CRS of 3.0, the models are estimated.

Figure 50 and Figure 51 show the current and standard models for Districts 1 through 4 and 5 through 9, respectively. Both current models are above the majority of the data between a CRS of 9.0 and 6.5. The new models more closely approximate the data in that CRS range. The data are sparse and rather random, so the models should be revisited for accuracy as more data becomes available.

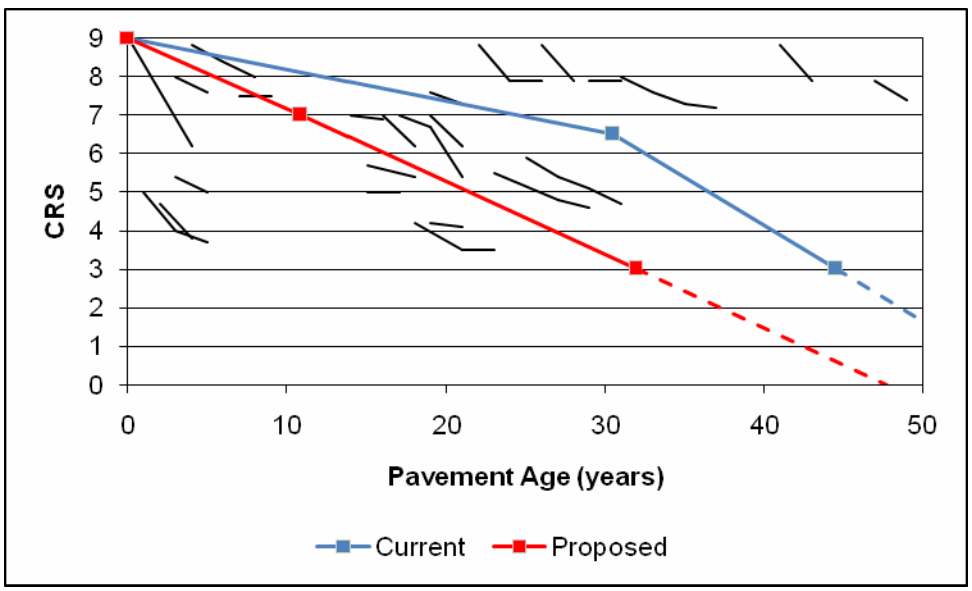

Figure 50. Non-interstate JPCP, districts 1 through 4.

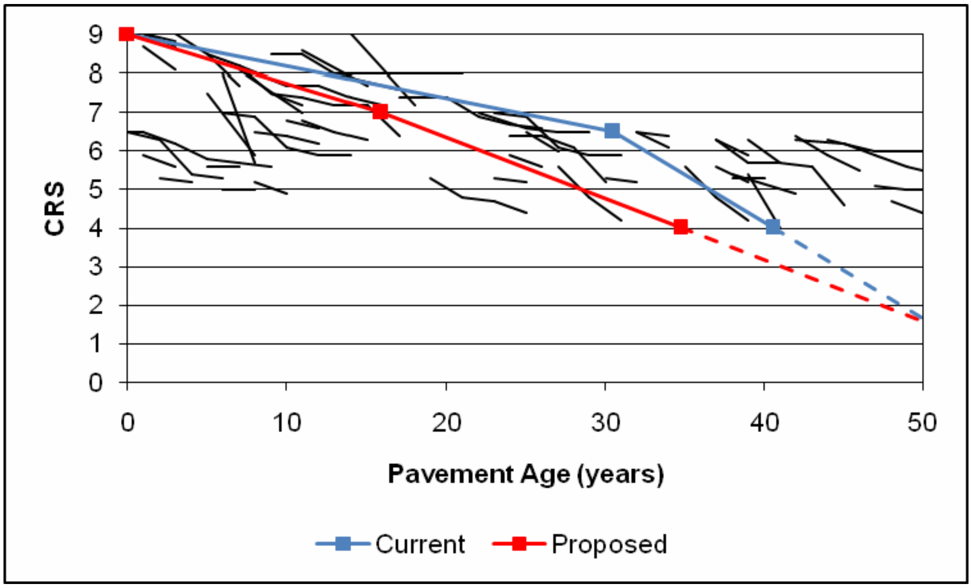

Figure 51. Non-interstate JPCP, districts 5 through 9.

Table 46 lists the number of years required for the models to reach CRS values of 4.5. All pavements of this type, regardless of D-cracking and area of the state, are expected to have shorter life spans using the proposed models. The proposed models more closely match the data than the current models.

Table 46. Non-interstate JPCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	38.5	24.0
	5 – 9	38.5	31.6
D-cracking	1 – 9	38.5	23.4

4.21 NON-INTERSTATE HJCP

The current and proposed models for hinge-jointed concrete pavements are listed in Table 47. There was no benefit to splitting the Districts into 1 through 4 and 5 through 9 for the standard models. The D-cracking sections were combined with partially and fully reinforced jointed concrete pavements to ensure sufficient data for modeling. The district split was beneficial for that data set. SMART modeling does not apply to this pavement type.

Table 47. Non-Interstate HJCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.109	0.109	0.111	0.088
D-Cracking	1 – 4	0.210	0.272	0.232	0.232
	5 – 9	0.210	0.272	0.198	0.198

Note: Below CRS of 6.0, the models are estimated.

The vast majority of the data for hinge-jointed concrete pavements is above a CRS of 7.0, as seen in Figure 52. The proposed model predicts slightly more deterioration in that range than the current model. As the pavements age past CRS 7.0, the model should be revisited to ensure proper prediction modeling at lower CRS levels.

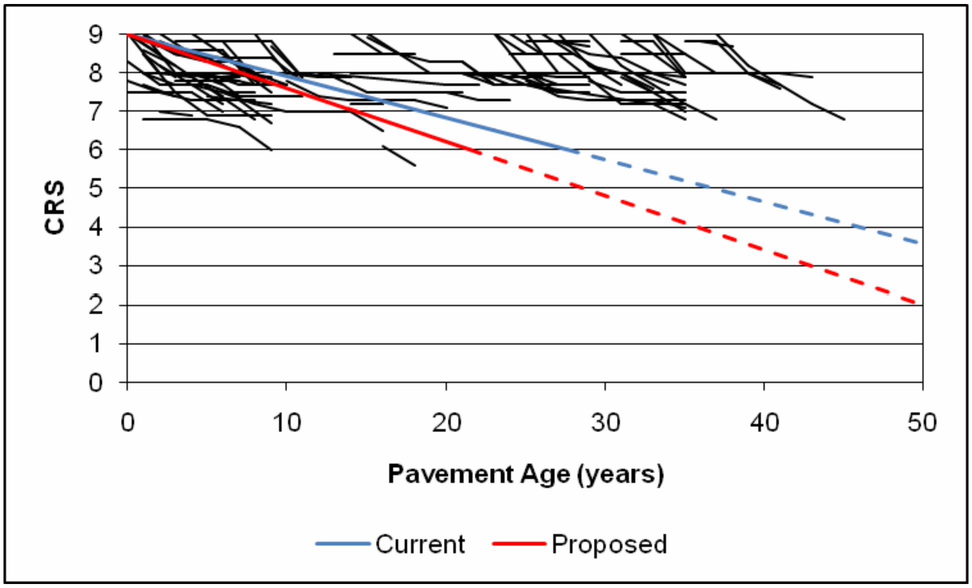

Figure 52. Non-interstate HJCP, all districts.

Figure 53 shows the data, and current and proposed D-cracking models for hinge-jointed, partially reinforced and fully reinforced concrete pavements in Districts 1 through 4. The proposed model is similar to the current model. Sections that are less than 20 years old may have been misidentified as D-cracking or have incorrect age information.

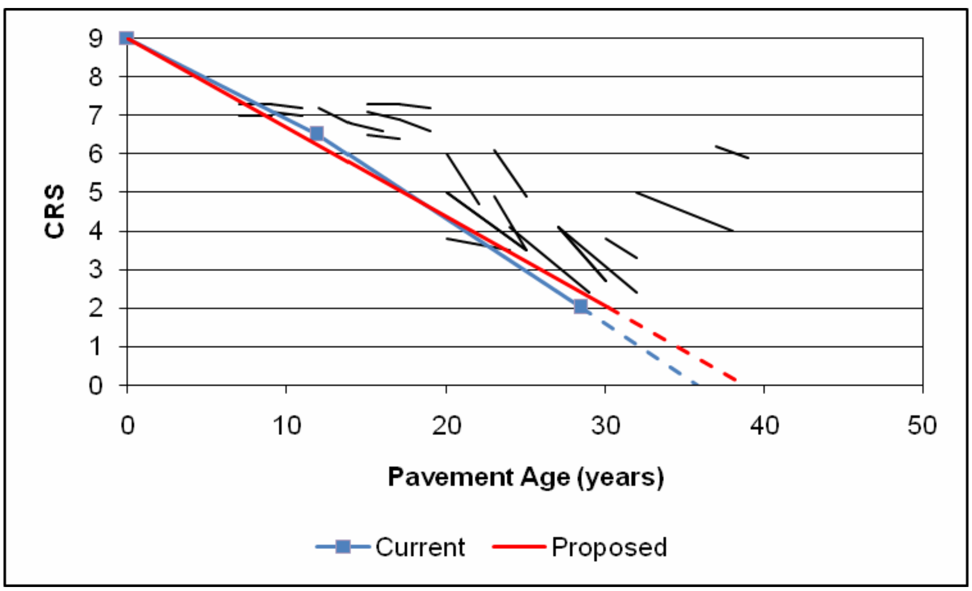

Figure 53. D-cracking non-interstate HJCP and JRCP, districts 1 through 4.

Figure 54 shows the data, current model, and proposed D-cracking model for hinge-jointed, partially reinforced and fully reinforced concrete pavements in Districts 5 through 9. The proposed model is nearly identical to the current model above a CRS of 6.5. Below a CRS of 6.5, the proposed model predicts slower deterioration than the current model.

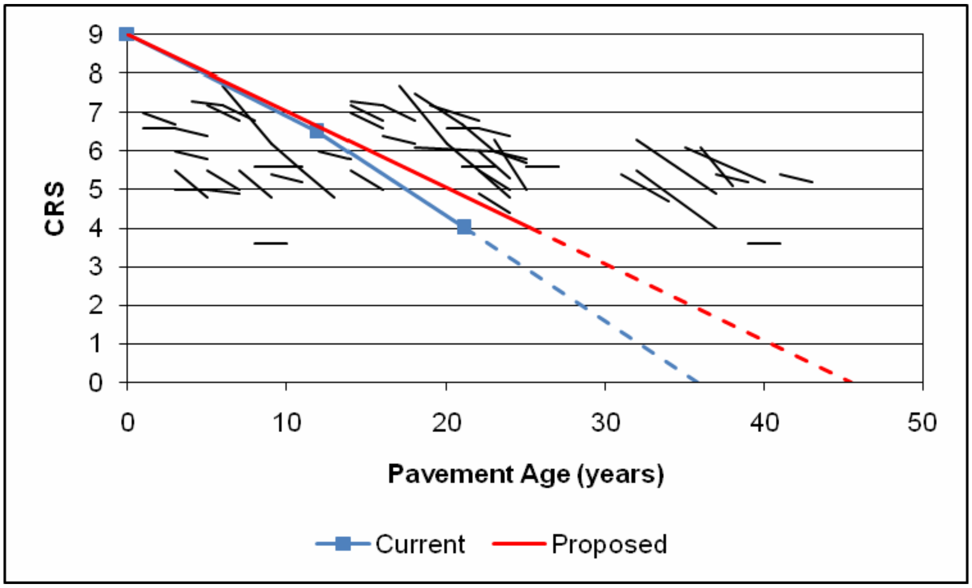

Figure 54. D-cracking non-interstate HJCP and JRCP, districts 5 through 9.

The years required to reach CRS values of 4.5 are detailed in Table 48. The standard models predict a shorter life, while the D-cracking models predict a similar life, as compared to the current models.

Table 48. Non-interstate HJCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	41.3	32.1
D-cracking	1 – 4	19.3	19.4
	5 – 9	19.3	22.7

4.22 NON-INTERSTATE JRCP

Table 49 details the current and proposed models for partially and fully reinforced concrete pavements. The standard model did not benefit by dividing the data by area of the state. Again, the D-cracking data for this pavement type was combined with that of the hinge-jointed concrete pavements for modeling purposes. SMART modeling does not apply to this pavement type.

Table 49. Non-Interstate JRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.210	0.272	0.137	0.163
D-Cracking	1 – 4	0.210	0.272	0.232	0.232
	5 – 9	0.210	0.272	0.198	0.198

Note: Below CRS of 3.0, the models are estimated.

The proposed standard model predicts much less deterioration than the current standard model, as seen in Figure 55. The proposed model runs through the center of the bulk of the data.

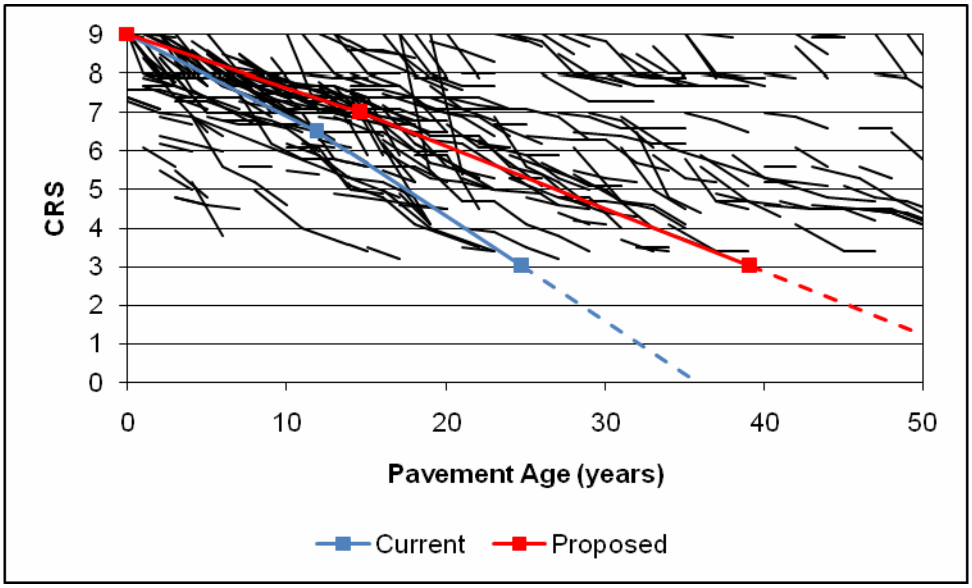

Figure 55. Non-interstate JRCP, all districts.

Table 50 contains the number of years until the models reach CRS values of 4.5.

Table 50. Non-interstate JRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	19.3	30.0
D-cracking	1 – 4	19.3	19.4
	5 – 9	19.3	22.7

4.23 NON-INTERSTATE CRCP

The current and proposed models for continually reinforced concrete pavements are contained in Table 51. There was no benefit to modeling Districts 1 through 4 and 5 through 9 separately, for either the standard or D-cracking model. SMART modeling does not apply to this pavement type.

Table 51. Non-Interstate CRCP Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 9	0.135	0.230	0.096	0.136
D-Cracking	1 – 9	0.135	0.230	0.187	0.203

Note: Below CRS of 4.0, the models are estimated.

Figure 56 shows the current and proposed standard models, and the data used for model development. The proposed model predicts slower deterioration than the current model, and lines up very well with the data.

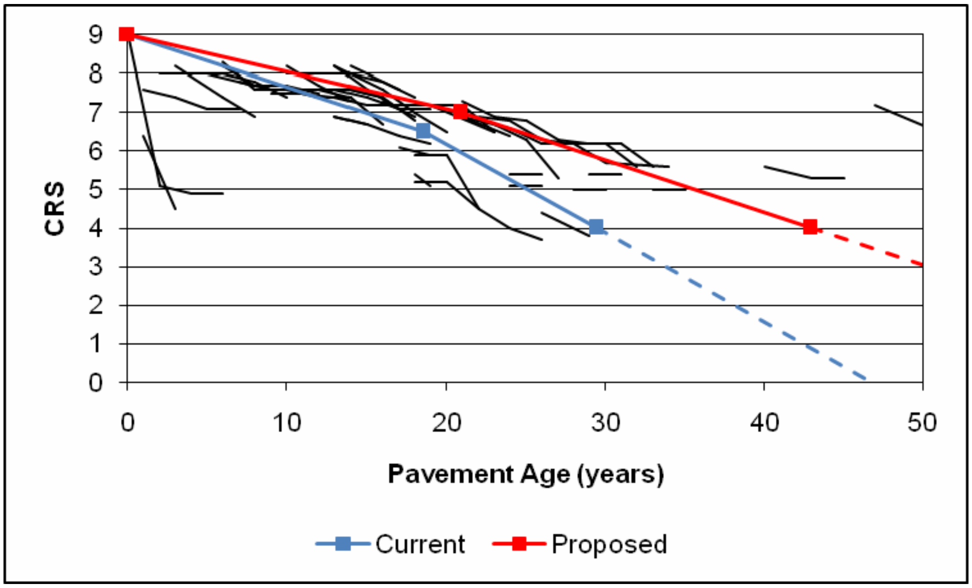

Figure 56. Non-interstate CRCP, all districts.

The current and proposed D-cracking models are shown in Figure 57. The proposed model predicts slightly faster deterioration than the current model. Again, the sections younger than 20 years of age have either been misidentified as D-cracking or have incorrect age information.

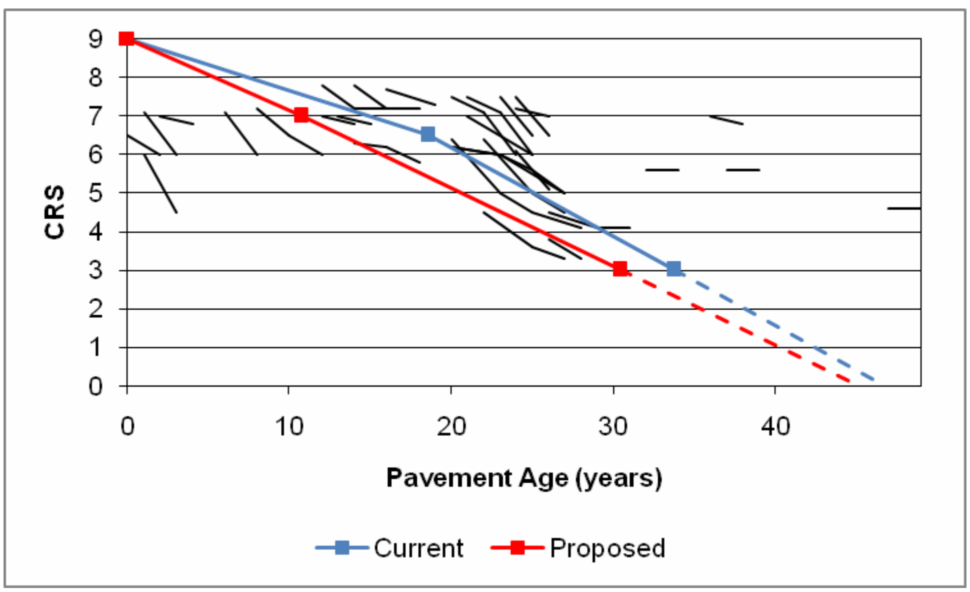

Figure 57. D-cracking non-interstate CRCP, all districts.

The number of years needed until the models reach CRS values of 4.5 are included in Table 52. The standard model predicts a longer life span than the current model, while the proposed D-cracking model is similar to the current D-cracking model.

Table 52. Non-interstate CRCP Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 9	27.2	39.2
D-cracking	1 – 9	27.2	23.0

4.24 NON-INTERSTATE BBO

There was very little data for pavements made of brick, block, or other material. No models currently exist for this pavement type. Table 53 lists the model for this pavement type.

Table 53. Non-Interstate BBO Models

Model Type	Districts	Proposed Slopes CRS 9.0 – 7.0	Proposed Slopes CRS 7.0 – 1.0
Standard	1 – 9	0.170	0.170

Note: Below CRS of 8.0, the models are estimated.

The data and proposed standard model are shown graphically in Figure 58. There was only one data section for analysis. If more data become available, the model should be revised.

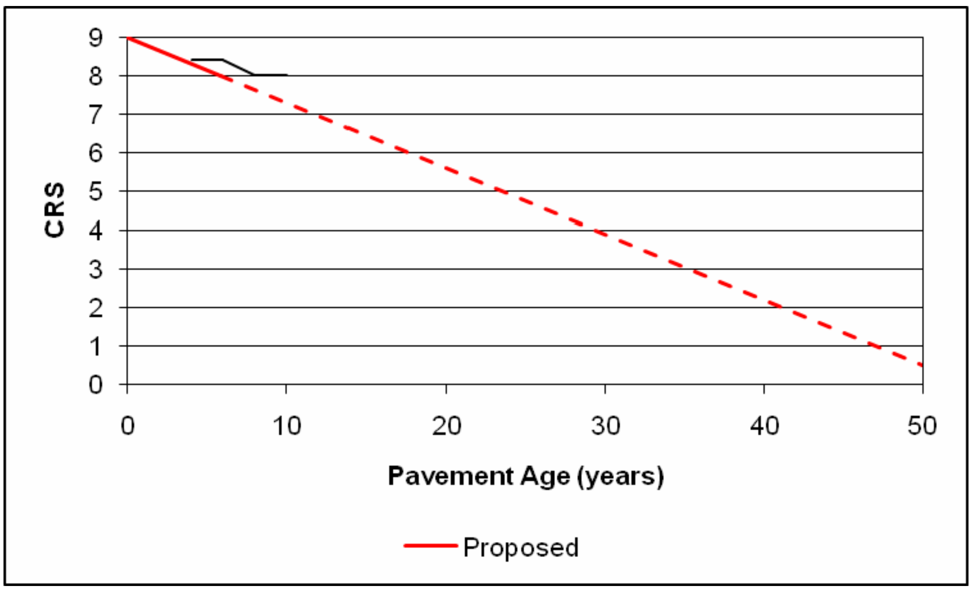

Figure 58. Non-interstate BBO, all districts.

Table 54 details the number of years required for the models to reach CRS values of 4.5. There are no current models available for comparison.

Table 54. Non-interstate BBO Years to CRS 4.5

Model Type	Districts	Proposed (years)
Standard	1 – 9	26.5

4.25 NON-INTERSTATE COMBINATION TYPE PAVEMENTS (95X, 96X, 97X)

The type 95x combination pavements are predominantly full-depth asphalt pavements, with any other kind of pavement as the other part of the combination. The current and proposed models for this pavement type are listed in Table 55. Because full-depth asphalt is predominant, no D-cracking model is needed.

Table 55. Non-Interstate Combination Type Pavements (95x) Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 9	0.281	0.281	0.191	0.191
SMART	1 – 9	None	None	0.517	0.517

Note: Below CRS of 4.0, the models are estimated.

The amount of data for model development was limited. The data, current standard, and proposed standard models are shown in Figure 59. The proposed model predicts slower deterioration of this pavement type than the current model.

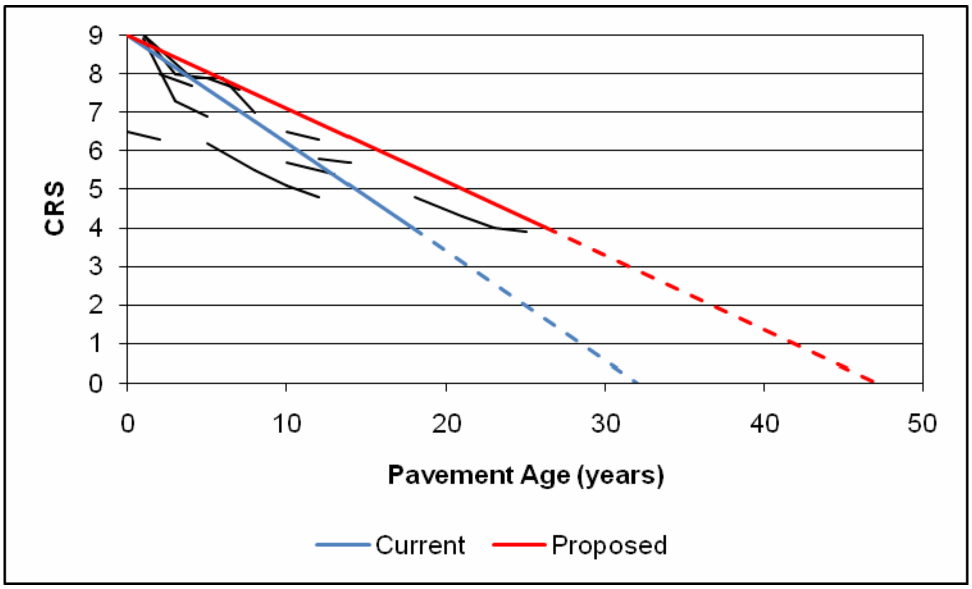

Figure 59. Non-interstate 95x, all districts.

There were only two pavement traces available for SMART model development. The data and proposed SMART model are shown in Figure 60. The model should be revised as more data become available.

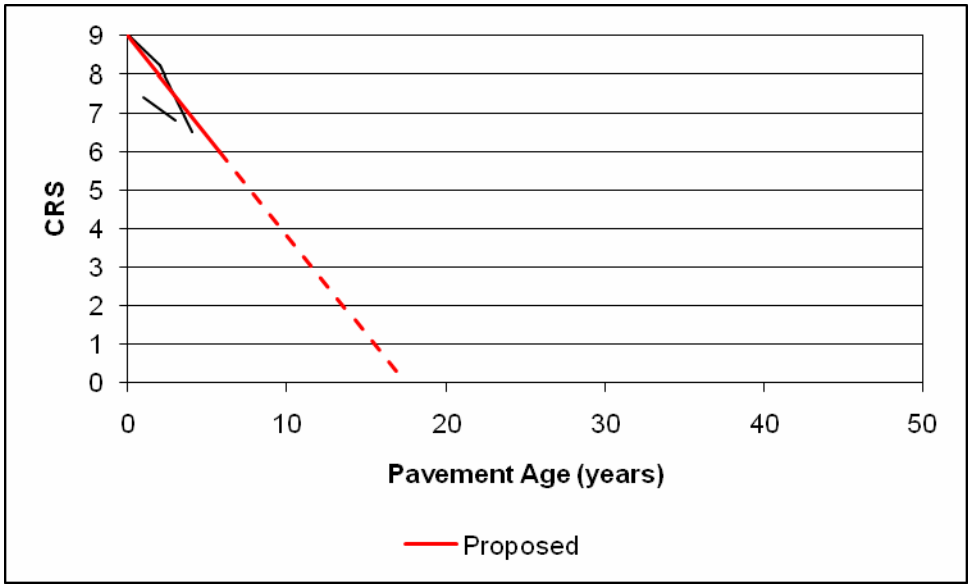

Figure 60. SMART non-interstate 95x, all districts.

The number of years required for the 95x combination pavements to reach CRS values of 4.5 are contained in Table 56. Standard pavements are predicted to last longer, using the proposed model. There is currently no model for SMART pavements for comparison.

Table 56. Non-interstate Combination 95x Years to CRS 4.5

		Current	Proposed
Model Type	Districts	(years)	(years)
Standard	1 – 9	16.0	23.6
SMART	1 – 9	None	8.7

The type 96x combination pavements are predominantly asphalt overlays of concrete pavements. The current and proposed models are detailed in Table 57. Dividing the Districts into 1 through 4 and 5 through 9 and break points were beneficial in developing the standard models.

Table 57. Non-Interstate Combination 96x Pavements Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 5.5	CRS 5.5 – 1.0
Standard	1 – 4	0.298	0.208	0.442	0.197
	5 – 9	0.298	0.208	0.287	0.150
D-Cracking	1 – 4	0.298	0.208	0.326	0.326
	5 – 9	0.456	0.456	0.326	0.326
SMART	1 – 4	0.440	0.219	0.414	0.414
	5 – 9	0.325	0.204	0.414	0.414

Note: Below CRS of 4.0, the models are estimated.

Figure 61 and Figure 62 show the current and proposed standard models for this pavement type. The Districts 1 through 4 model predicts faster deterioration than the current model, while the Districts 5 through 9 model is nearly identical to the current model through a CRS of 4.0.

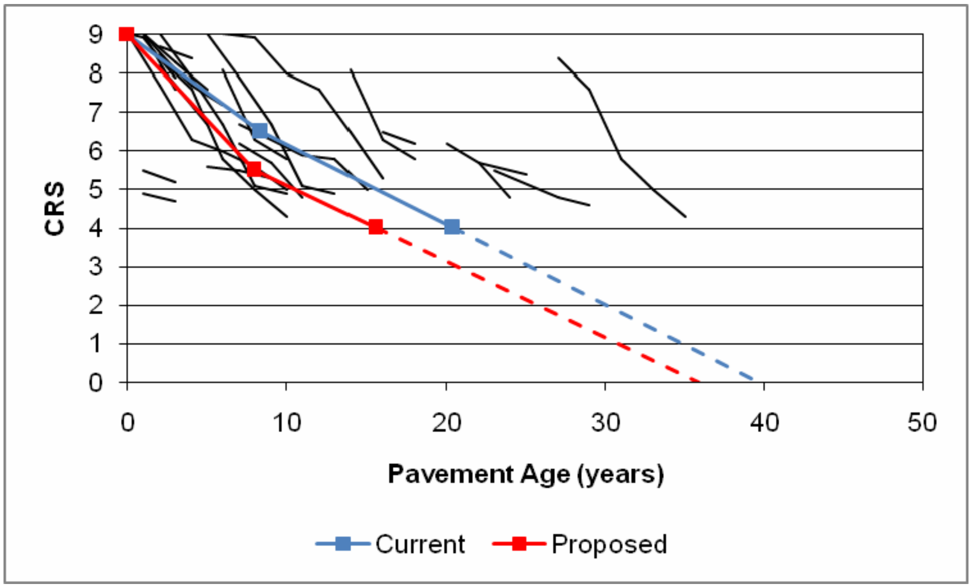

Figure 61. Non-interstate 96x, districts 1 through 4.

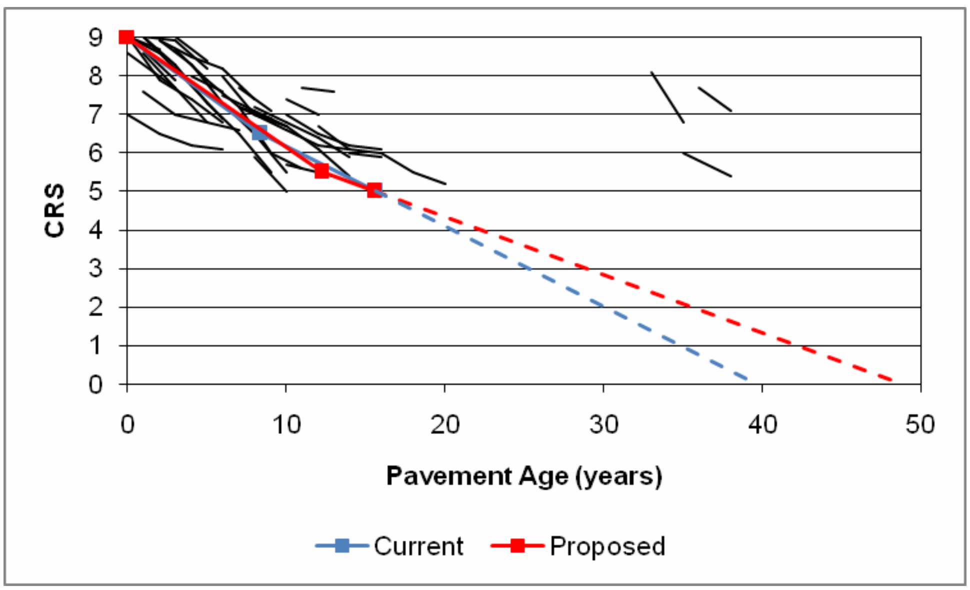

Figure 62. Non-interstate 96x, districts 5 through 9.

There was only one trace available for D-cracking model development. The data, current model, and proposed D-cracking model are shown in Figure 63. Again, the model should be revised if more data become available.

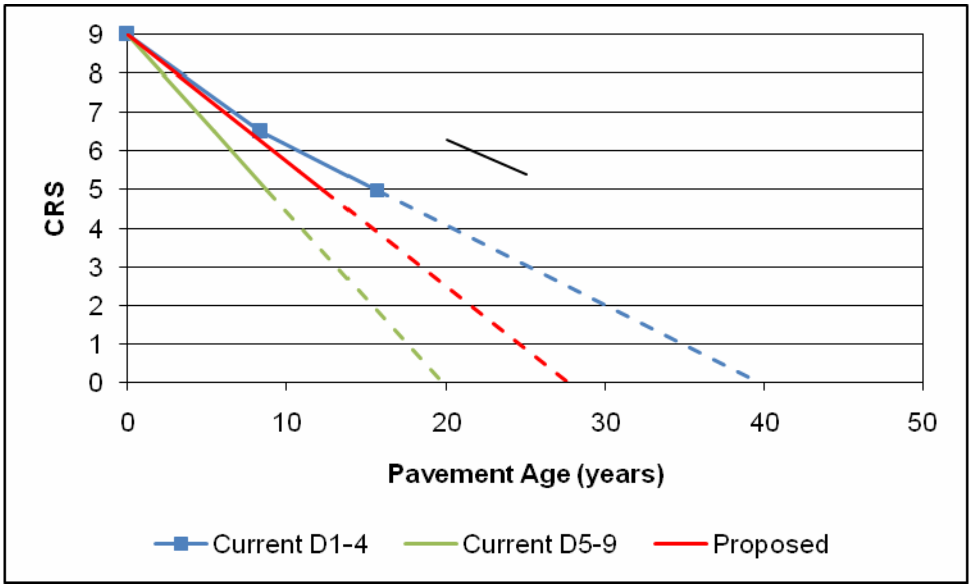

Figure 63. D-cracking non-interstate 96x, all districts.

The current and proposed SMART models are shown in Figure 64. Both current models and the proposed model are very similar through a CRS of 6.5. There is only one trace that extends below a CRS of 6.5. As more data become available, the model should be revised, particularly at the lower CRS range.

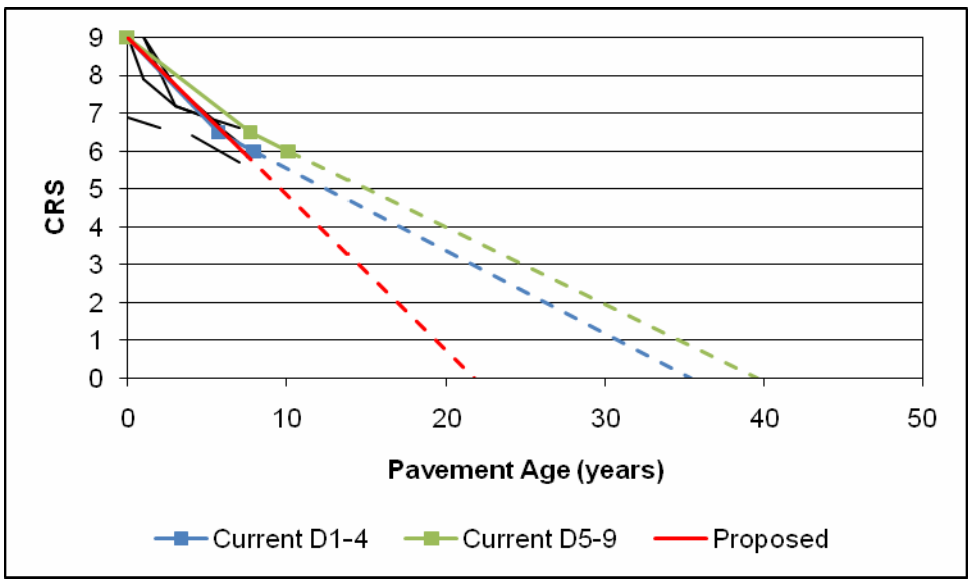

Figure 64. SMART non-interstate 96x, all districts.

The number of years required for the models to reach CRS values of 4.5 are listed in Table 58. Standard and D-cracking pavements in the northern districts are predicted to last a shorter amount of time using the proposed models, while standard pavements in the southern districts are expected to last approximately the same amount of time. SMART projects are predicted to last a shorter amount of time using the proposed models.

Table 58. Non-interstate Combination 96x Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	18.0	13.0
	5 – 9	18.0	18.9
D-cracking	1 – 4	18.0	13.8
	5 – 9	9.9	13.8
SMART	1 – 4	14.8	10.9
	5 – 9	17.5	10.9

The type 97x combination pavements are predominantly bare concrete pavements. The current and proposed models are detailed in Table 59. Dividing districts by area of the state and using break points improved the accuracy of the standard models. Due to the limited amount of D-cracking data, the districts were not separated and break points were not used in that model.

Table 59. Non-Interstate Combination Type Pavements (97x) Models

		Current Slopes		Proposed Slopes	
Model Type	Districts	CRS 9.0 – 6.5	CRS 6.5 – 1.0	CRS 9.0 – 7.0	CRS 7.0 – 1.0
Standard	1 – 4	0.280	0.326	0.329	0.197
	5 – 9	0.280	0.326	0.223	0.168
D-Cracking	1 – 9	0.280	0.326	0.439	0. 439

Note: Below CRS of 4.0, the models are estimated.

Figure 65 and Figure 66 show the data, current standard, and proposed standard models for Districts 1 through 4 and 5 through 9, respectively. Both proposed models are similar to the existing models at CRS values above 6.5. Below CRS 6.5, the proposed models predict slower deterioration.

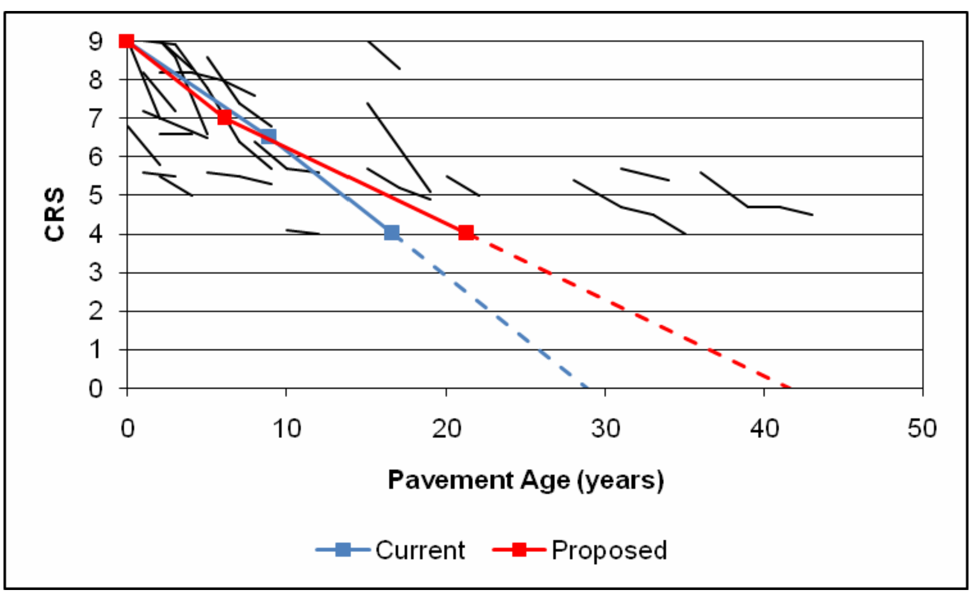

Figure 65. Non-interstate 97x, districts 1 through 4.

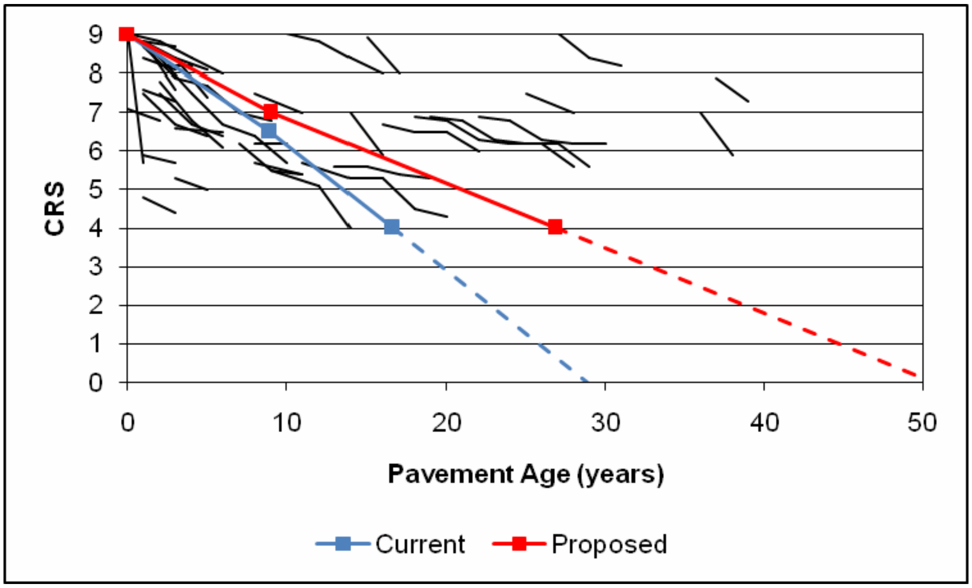

Figure 66. Non-interstate 97x, districts 5 through 9.

The proposed model for D-cracking concrete-predominant combination pavements is shown in Figure 67. Due to the limited amount of data, the model should be revised in the future, as more data becomes available.

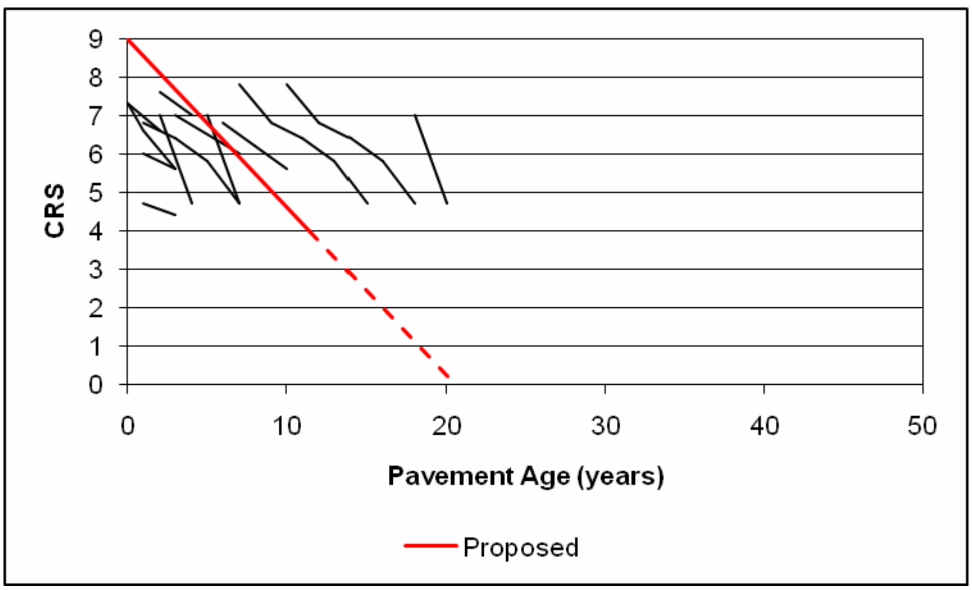

Figure 67. D-cracking non-interstate 97x, all districts.

Table 60 enumerates the number of years for the models to reach CRS values of 4.5. Standard pavements are predicted to last a longer amount of time using the proposed models. There are no current D-cracking models for comparison.

Table 60. Non-interstate Combination 97x Years to CRS 4.5

Model Type	Districts	Current (years)	Proposed (years)
Standard	1 – 4	15.1	18.8
	5 – 9	15.1	23.8
D-cracking	1 – 9	None	10.3

4.26 D-CRACKING AND SMART LOSS OF LIFE

After model development was completed, the age of D-cracking models at a CRS value of 4.5 was compared to that of the standard models. The results of the D-cracking analysis are presented in Table 61.

Table 61. Loss of Life Due to D-cracking

			Loss of Life to 4.5	
System	Pavement Type	Districts	Current %	Proposed %
Interstate	600/610/615	1 - 4		0.0
		5 - 9		40.6
	625	1 - 4	0.0	0.0
		5 - 9	73.2	40.3
	620/630	1 - 4	0.0	0.0
		5 - 9	19.9	40.3
	640	1 - 4	19.9	0.0
		5 - 9	19.8	31.7
	725/775	1 - 4	67.7	37.7
		5 - 9	67.7	37.7
	720/730/770/780	1 - 4	0.0	2.0
		5 - 9	0.0	2.0
	740/792	1 - 4	5.3	23.4
		5 - 9	5.3	23.4
	95x/96x	1 - 4	60.0	18.9
		5 - 9	60.0	18.9
	97x	1 - 4	5.3	39.3
		5 - 9	5.3	39.3

(continued on next page)

Table 61. Loss of Life Due to D-Cracking (continued)

System	Pavement Type	Districts	Loss of Life to CRS 4.5 Current %	Proposed %
Non-Interstate	600	1 - 4	0.0	27.4
		5 - 9	32.0	27.4
	610	1 - 4	0.0	4.5
		5 - 9	47.2	22.6
	620/625630	1 - 4	0.0	9.3
		5 - 9	51.0	29.4
	640	1 - 4	0.0	12.4
		5 - 9	34.4	12.4
	650	1 - 4	0.0	11.2
		5 - 9	54.4	29.4
	700/760	1 - 4	0.0	30.4
		5 - 9	0.0	30.4
	710/765/767	1 - 4	0.0	2.5
		5 - 9	0.0	25.9
	725/775	1 - 4	28.3	39.6
		5 - 9	28.3	29.3
	720/730/770/772 777/780/782	1 - 4	0.0	35.3
		5 - 9	0.0	55.8
	740/790/792	1 - 4	0.0	41.3
		5 - 9	0.0	41.3
	96x	1 - 4		-6.2
		5 - 9		27.0
	97x	1 - 4		45.2
		5 - 9		56.7

The average loss of life to a CRS of 4.5 due to D-cracking is as follows:

- Interstate asphalt overlays: 19%
- Interstate jointed concrete: 20%
- Interstate CRCP: 23%
- Non-interstate asphalt overlays: 19%
- Non-interstate jointed concrete: 31%
- Non-interstate CRCP: 41%

The age of SMART models at a CRS value of 4.5 was compared to that of the standard models. The results of the SMART analysis are presented in Table 62.

Table 62. Loss of Life Due to SMART Program

System	Pavement Type	Districts	Loss of Life to 4.5 Current %	Proposed %
Interstate	600/610/615	1 - 4		14.8
		5 - 9		14.8
	625	1 - 4	-3.0	24.3
		5 - 9	-29.5	31.2
	620/630	1 - 4	-80.6	24.3
		5 - 9	-72.9	31.2
	640	1 - 4	-53.1	0.0
		5 - 9	-39.5	0.0
Non-interstate	400/410	1 - 4		3.3
		5 - 9		3.3
	500	1 - 4	0.0	17.4
		5 - 9	0.0	17.4
	550/560	1 - 4	15.8	6.4
		5 - 9	40.5	-3.1
	600	1 - 4	7.8	6.3
		5 - 9	-3.9	6.3
	610	1 - 4	-3.8	6.8
		5 - 9	-4.4	2.4
	620/625630	1 - 4	-46.0	10.0
		5 - 9	-3.5	18.9
	640	1 - 4	0.0	-6.9
		5 - 9	0.0	-6.9
	650	1 - 4		-23.1
		5 - 9		2.2
	95x	1 - 4		63.1
		5 - 9		63.1
	96x	1 - 4	11.5	16.2
		5 - 9	0.3	42.3

The average loss of life to a CRS of 4.5 due to SMART program overlays is as follows:

- Interstate asphalt overlays: 18%
- Non-interstate full-depth asphalt and asphalt overlays: 12%

D-cracking and SMART have approximately the same negative effect on the life on asphalt overlays. D-cracking has a greater effect on bare concrete pavements, particularly off the interstate system, than it does on overlays of concrete pavements.

There were nine records that were flagged for both D-cracking and SMART. Model development from this data set was not possible, because no traces could be built from the data. Because both the presence of D-cracking and the use of SMART overlays are detrimental to pavements, it is recommended that SMART overlays not be permitted on pavement sections with identified D-cracking.

5. SUMMARY AND CONCLUSIONS

Standard, D-cracking, and SMART prediction models were developed or revised for as many pavement types as possible. Models were developed for the pavement types shown in Table 63.

Table 63. Prediction Models Created and Revised

System	Pavement Type	Standard	D-cracking	SMART
Interstate	ACP	R	N/A	I
	AC/JPCP	C	C	C
	AC/JRCP	R	R	R
	AC/CRCP	R	R	R
	JRCP	R	R	N/A
	HJCP	R	R	N/A
	CRCP	R	R	N/A
	Combination 95x and 96x	R	R	I
	Combination 97x	R	R	N/A
Non-Interstate	Unimproved	I	I	I
	ACSTLT	C	N/A	I
	ACPLT	C	N/A	C
	ACSTHT	R	N/A	R
	AC/Rubb	C	N/A	C
	ACP	R	N/A	R
	AC/PCCun	R	R	R
	AC/JPCP	R	R	R
	AC/JRCP	R	R	R
	AC/CRCP	R	R	R
	AC/BBO	R	R	R
	PCCun	R	R	N/A
	JPCP	R	R	N/A
	JRCP	R	R	N/A
	HJCP	R	R	N/A
	CRCP	R	R	N/A
	BBO	R	I	N/A
	Combination 94x	I	I	I
	Combination 95x	R	N/A	C
	Combination 96x	R	R	R
	Combination 97x	R	R	N/A
	Combination 98x	I	N/A	N/A

C = created R = revised I = insufficient data N/A = not applicable

The current and proposed prediction models, as well as the current and proposed years to CRS values of 4.5, are summarized in Appendix B.

The grouping of districts into northern and southern areas for the purpose of model development was examined. Currently, the northern area consists of Districts 1 through 4, and the southern area includes Districts 5 through 9. For asphalt-surfaced pavements, this grouping continues to be accurate. For concrete pavements, the area of the state appears to have no impact on performance.

The break point between the upper and lower CRS ranges was also examined. Models were created for all pavement types using the current 6.5 break point, and a new graphing procedure was created to enable visualizing accuracy. It was determined that using a 5.5 break point for asphalt-surfaced pavements and a 7.0 break point for concrete pavements increased accuracy. Additionally, removing flats, where the CRS did not change between consecutive surveys, increased the accuracy of the models for asphalt-surfaced pavements. For concrete pavements, the flats were kept in the analysis, as the models would have been less accurate if they were removed. It is reasonable for concrete pavements to stay at the same CRS value for consecutive surveys.

The D-cracking and SMART models were compared to the standard models to determine the effect of D-cracking aggregate and thinner overlays, respectively, had on the expected life of pavement sections. D-cracking was found to decrease a pavement's life to a CRS of 4.5 between 19 and 41 percent, with the greater loss on bare concrete pavements. SMART overlays were found to decrease the expected life to a CRS of 4.5 between 12 and 18 percent.

The following models should be revised as more data become available:

- Interstate ACP standard
- Interstate combination 9xx D-cracking
- Non-interstate ACPLT SMART
- Non-interstate ACSTHT SMART
- Non-interstate AC/Rubb standard
- Non-interstate AC/BBO SMART
- Non-interstate JPCP standard
- Non-interstate BBO standard
- Non-interstate combination 95x SMART
- Non-interstate combination 96x D-cracking and SMART
- Non-interstate combination 97x D-cracking

A final report will be written summarizing the updating of the CRS calculation and prediction models.

6. REFERENCES

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Hall, K.T., Y. Lee, M.I. Darter, and D.L. Lippert. *Forecasting Pavement Rehabilitation Needs for the Illinois Interstate Highway System*. Washington, D.C. Transportation Research Board. 1994.

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APPENDIX A. IRIS SURFACE TYPES AND CODES

Table 64. IRIS Surface Types and Codes

Code	Description
010	Unimproved
020	Graded and Drained
100	Soil-Surfaced – without dust palliative treatment
110	Soil-Surfaced – with dust palliative treatment
200	Gravel or stone – without dust palliative treatment
210	Gravel or stone – with dust palliative treatment
300	Bituminous Surface-Treated (low type bituminous)
400	Mixed Bituminous (low type bituminous)
410	Bituminous Penetration (low type bituminous)
500	Bituminous Surface Treated (high type bituminous)
501	High Type Bituminous over PCC Rubblized (reinforcement unknown)
510	High Type Bituminous over PCC Rubblized (no reinforcement)
520	High Type Bituminous over PCC Rubblized (partial reinforcement)
525	High Type Bituminous over PCC Rubblized (hinged joints)
530	High Type Bituminous over PCC Rubblized (full reinforcement)
540	High Type Bituminous over PCC Rubblized (continuous reinforcement)
550	Bituminous Concrete (non Class I), Sheet Rock or Rock Asphalt
560	Bituminous Concrete Pavement (full-depth)
600	High Type Bituminous over PCC (reinforcement unknown)
610	High Type Bituminous over PCC (no reinforcement)
615	High Type Bituminous over PCC (no reinforcement, short panels/dowels)
620	High Type Bituminous over PCC (partial reinforcement)
625	High Type Bituminous over PCC (hinged joints)
630	High Type Bituminous over PCC (full reinforcement)
640	High Type Bituminous over PCC (continuous reinforcement)
650	High Type Bituminous over brick, block, or other
700	PCC – reinforcement unknown
710	PCC – no reinforcement
720	PCC – partial reinforcement
725	PCC – hinged joints
730	PCC – full reinforcement
740	PCC – continuous reinforcement
760	Non-reinforced over PCC (reinforcement unknown)
762	Reinforced over PCC (reinforcement unknown)
765	Non-reinforced over PCC (no reinforcement)
767	Reinforced over PCC (no reinforcement)
770	Non-reinforced over PCC (partial reinforcement)
772	Reinforced over PCC (partial reinforcement)
775	Non-reinforced over PCC (hinged joints)
777	Reinforced over PCC (hinged joints)
780	Non-reinforced over PCC (full reinforcement)
782	Reinforced over PCC (full reinforcement)
790	Non-reinforced over PCC (continuous reinforcement)
792	Reinforced over PCC (continuous reinforcement)
800	Brick, Block, or Other
9xx	Combination

APPENDIX B. PROPOSED MODELS AND YEARS TO CRS 4.5

Table 65. Interstate Proposed Models

System	Pavement Type	Districts	Standard 9.0 - 5.5	Standard 5.5 - 1.0	D-Cracking 9.0 - 5.5	D-Cracking 5.5 - 1.0	SMART 9.0 - 5.5	SMART 5.5 - 1.0
Interstate	550/560	1 - 4	0.451	0.451				
		5 - 9	0.272	0.272				
	600/610	1 - 4	0.299	0.264	0.275	0.286	0.425	0.200
		5 - 9	0.299	0.264	0.491	0.491	0.425	0.200
	625/615	1 - 4	0.358	0.239	0.333	0.253	0.426	0.426
		5 - 9	0.331	0.206	0.491	0.491	0.426	0.426
	620/630	1 - 4	0.358	0.239	0.333	0.253	0.426	0.426
		5 - 9	0.331	0.206	0.491	0.491	0.426	0.426
	640	1 - 4	0.356	0.356	0.356	0.356	0.356	0.356
		5 - 9	0.270	0.270	0.395	0.395	0.270	0.270
	725/775	1 - 4	0.140	0.140	0.225	0.225		
		5 - 9	0.140	0.140	0.225	0.225		
	720/730/770/780	1 - 4	0.213	0.228	0.225	0.225		
		5 - 9	0.213	0.228	0.225	0.225		
	740/792	1 - 4	0.144	0.165	0.203	0.203		
		5 - 9	0.144	0.165	0.203	0.203		
	95x/96x	1 - 4	0.314	0.314	0.388	0.388		
		5 - 9	0.314	0.314	0.388	0.388		
	97x	1 - 4	0.221	0.248	0.388	0.388		
		5 - 9	0.221	0.248	0.388	0.388		

Table 66. Interstate Proposed Years to CRS 4.5

System	Pavement Type	Districts	Standard (years)	D-Cracking (years)	SMART (years)
Interstate	550/560	1 - 4	10.0		
		5 - 9	16.5		
	600/610/615	1 - 4	15.5		13.2
		5 - 9	15.5	9.2	13.2
	620/625/630	1 - 4	14.0		10.6
		5 - 9	15.4	9.2	10.6
	640	1 - 4	12.6		
		5 - 9	16.7	11.4	
	725/775	1 - 4	32.1	20.0	
		5 - 9	32.1	20.0	
	720/730/770/780	1 - 4	20.4	20.0	
		5 - 9	20.4	20.0	
	740/792	1 - 4	29.0	22.2	
		5 - 9	29.0	22.2	
	95x/96x	1 - 4	14.3	11.6	
		5 - 9	14.3	11.6	
	97x	1 - 4	19.1	11.6	
		5 - 9	19.1	11.6	

Table 67. Non-Interstate Proposed Models

System	Pavement Type	Districts	Standard 9.0 - 5.5	Standard 5.5 - 1.0	D-Cracking 9.0 - 5.5	D-Cracking 5.5 - 1.0	SMART 9.0 - 5.5	SMART 5.5 - 1.0
Non-Interstate	300	1 - 4	0.451	0.451	N/A	N/A	None	None
		5 - 9	0.451	0.451	N/A	N/A	None	None
	400/410	1 - 4	0.374	0.374	N/A	N/A	0.388	0.388
		5 - 9	0.374	0.374	N/A	N/A	0.388	0.388
	500	1 - 4	0.322	0.248	N/A	N/A	0.367	0.367
		5 - 9	0.322	0.248	N/A	N/A	0.367	0.367
	520/530	1 - 4	0.825	0.825	N/A	N/A	None	None
		5 - 9	0.825	0.825	N/A	N/A	None	None
	550/560	1 - 4	0.350	0.251	N/A	N/A	0.392	0.240
		5 - 9	0.297	0.225	N/A	N/A	0.317	0.181
	600	1 - 4	0.293	0.181	0.353	0.353	0.325	0.121
		5 - 9	0.293	0.181	0.353	0.353	0.332	0.242
	610	1 - 4	0.382	0.244	0.353	0.353	0.419	0.250
		5 - 9	0.303	0.203	0.353	0.353	0.329	0.185
	625	1 - 4	0.372	0.216	0.353	0.353	0.417	0.236
		5 - 9	0.303	0.155	0.353	0.353	0.359	0.208
	620/630	1 - 4	0.372	0.216	0.353	0.353	0.417	0.236
		5 - 9	0.303	0.155	0.353	0.353	0.359	0.208
	640	1 - 4	0.356	0.216	0.353	0.353	0.290	0.290
		5 - 9	0.356	0.216	0.353	0.353	0.290	0.290
	650	1 - 4	0.407	0.174	0.353	0.353	0.399	0.113
		5 - 9	0.288	0.171	0.353	0.353	0.399	0.113
	700/760	1 - 4	0.141	0.129	0.192	0.192	N/A	N/A
		5 - 9	0.141	0.129	0.192	0.192	N/A	N/A
	710/765/767	1 - 4	0.184	0.190	0.192	0.192	N/A	N/A
		5 - 9	0.126	0.159	0.192	0.192	N/A	N/A
	725/775	1 - 4	0.111	0.088	0.232	0.232	N/A	N/A
		5 - 9	0.111	0.088	0.198	0.198	N/A	N/A
	720/730/770/772	1 - 4	0.137	0.163	0.232	0.232	N/A	N/A
	777/780/782	5 - 9	0.137	0.163	0.198	0.198	N/A	N/A
	740/790/792	1 - 4	0.096	0.136	0.187	0.203	N/A	N/A
		5 - 9	0.096	0.136	0.187	0.203	N/A	N/A
	800	1 - 4	0.170	0.170	N/A	N/A	N/A	N/A
		5 - 9	0.170	0.170	N/A	N/A	N/A	N/A
	95x	1 - 4	0.191	0.191	N/A	N/A	0.517	0.517
		5 - 9	0.191	0.191	N/A	N/A	0.517	0.517
	96x	1 - 4	0.442	0.197	0.326	0.326	0.414	0.414
		5 - 9	0.287	0.150	0.326	0.326	0.414	0.414
	97x	1 - 4	0.329	0.197	0.439	0.439	N/A	N/A
		5 - 9	0.223	0.168	0.439	0.439	N/A	N/A

Table 68. Non-Interstate Proposed Years to CRS 4.5

System	Pavement Type	Districts	Standard (years)	D-Cracking (years)	SMART (years)
Non-interstate	300	1 - 4	10.0		
		5 - 9	10.0		
	400/410	1 - 4	12.0		11.6
		5 - 9	12.0		11.6
	500	1 - 4	14.9		12.3
		5 - 9	14.9		12.3
	501-540	1 - 4	5.5		
		5 - 9	5.5		
	550/560	1 - 4	14.0		13.1
		5 - 9	16.2		16.7
	600	1 - 4	17.5	12.7	19.0
		5 - 9	17.5	12.7	14.7
	610	1 - 4	13.3	12.7	12.4
		5 - 9	16.4	12.7	16.0
	620/625630	1 - 4	14.0	12.7	12.6
		5 - 9	18.0	12.7	14.6
	640	1 - 4	14.5	12.7	15.5
		5 - 9	14.5	12.7	15.5
	650	1 - 4	14.3	12.7	17.6
		5 - 9	18.0	12.7	17.6
	700/760	1 - 4	33.6	23.4	
		5 - 9	33.6	23.4	
	710/765/767	1 - 4	24.0	23.4	
		5 - 9	31.6	23.4	
	725/775	1 - 4	32.1	19.4	
		5 - 9	32.1	22.7	
	720/730/770/772 777/780/782	1 - 4	30.0	19.4	
		5 - 9	51.4	22.7	
	740/790/792	1 - 4	39.2	23.0	
		5 - 9	39.2	23.0	
	800	1 - 4	26.5		
		5 - 9	26.5		
	95x	1 - 4	23.6		8.7
		5 - 9	23.6		8.7
	96x	1 - 4	13.0	13.8	10.9
		5 - 9	18.9	13.8	10.9
	97x	1 - 4	18.8	10.3	
		5 - 9	23.8	10.3	

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